TAMPERE UNIVERSITY OF TECHNOLOGY

SEYFI BABACAN

PRODUCT AND PERFORMANCE DELIVERED: Supplying Customer with Products and Consecutive Delivery Performance Data

Master's Thesis

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ABSTRACT

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Supplier Oy (names will be kept confidential) is a Finnish joint venture established recently in the area of hydraulic hose assembly manufacturing for big Finnish OEMs. The company is considered to revolutionize the traditional methods of hydraulic hose assembly manufacturing by a majority of the industry experts. With the usage of extensive IT software and software driven machinery, it has now become the most effective hydraulic hose assembly manufacturing company, not only in Europe but in the whole world.

The idea was developed by a small team of people that combined creativity and experience. However, precise designing of every detail took a considerable amount of time. It is now believed that each detail that was considered during the design process, contributed to the implementation phase in a big portion. Author himself not only witnessed the design process, but also contributed to it in a deeper extent. Some tasks such as 3D design of the cells as well as whole factory layout and optimization of flows were led by the author primarily. After the design process was finalized, ramp-up phase started. Planning things on paper was one aspect, but actually building the whole factory from the scratch was a challenging task. After the ramp-up was completed successfully, development phase began. It was then necessary to make the small improvements in various areas, to improve processes and products, providing high level of customer satisfaction without sacrificing from the initial effectiveness of the whole idea.

In winter of 2012, this thesis was initiated with the aim of analyzing cost effectiveness of the case company. However soon after the initiation, the topic shifted to the area of supplying the customer not only products, but also own performance measurements. The reason for this shift was a recent turn of events during that time. Customer and the case company found a mismatch in their metrics. It was realized that on-time-delivery ratio was drastically different

according to two sides. Since both supplier and customer were in collaborative manner, they decided to investigate this mismatch and tried to solve it in a way that would be beneficial for both parties. After the investigation, some reasons for this mismatch were understood. Interestingly, supplier's metrics were yielding more accurate results than the metrics of customer. This raised the question from customer side whether they should use the supplier's metrics and hence the topic of the thesis shifted towards this more recent topic.

The concept of supplying metrics as well as products is found out to be a rather novel area in the literature. The literature review resulted in only few small sentences of such concept in different articles. Therefore, it became more interesting to research this topic and write the thesis in a way that also case company and its customer can benefit from it to a greater extent. The framework was built based on multiple smaller frameworks. Eventually, it combined three dimensions: (1) Lean manufacturing, (2) Customer-supplier relationships, (3) Performance measurement systems. It was revealed that supplying metrics was not a far away concept in lean partnerships considering the previous attempts already done under the concept of open book accounting (OBA). In other words, companies which were collaborative partners were already familiar to the sharing of internal information with each other. Only difference this time was the information was based on non-financial data whereas in OBA it was financial data only.

The findings of the thesis includes that sharing of vital information requires a certain level of trust and collaborative manner between parties. Lean manufacturing is proven to be an important driver in this trend of moving towards collaboration and close customer-supplier relationships. Based on the framework and logical deduction, shared metrics are in fact aligned with the complete philosophy of lean manufacturing. Since excessive performance measurement can also be considered as a waste (muda) in lean philosophy, sharing performance measures can easily yield to a reduction of total number of metrics between parties. Thus, both sides can benefit from this information sharing activity. Also, in case of a mismatch it is expected for collaborative parties to move towards troubleshooting to resolve any conflicts, which results in a more accurate performance measuring from the holistic viewpoint of the relationship. Finally, it is forecasted that sharing metrics can also initiate an improvement in other areas such as customer satisfaction or higher visibility of production.

PREFACE

This research was conducted on behalf of Supplier Oy, which can be perhaps considered as the first solid example of next generation hydraulic hose assembly manufacturing. Although the thesis started as an investigation of cost efficiency of Supplir Oy, it was changed to this current topic due to certain events. The research resulted in development of a generic framework which can be applied in cases where suppliers provide their customers not only products, but also some of their own performance measurements.

Wishing that I could state their names clearly here, I would like to thank whole Supplier Oy team whom I always enjoy working with. I also would like to thank to my parents separately for their endless support in my life.

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1 INTRODUCTION

Originating in the late 80s, the introduction of lean manufacturing influenced a lot of companies. The main reason for such influence was the benefits that it was promising such as cost reduction, increased throughput and higher quality (Chauhan & Singh, 2012). In today's business environment, lean manufacturing has become one of the widest known management and manufacturing philosophy followed by a lot of companies. In this chapter, some background information will be given, followed by the problem statement of the thesis. After explaining the objective of the thesis, some theory regarding research method and process will be explained.

1.1 BACKGROUND

The change towards lean manufacturing brought some radical changes to production environments as well as in other areas. With the slow evolution of purchasing behavior, customers were not only evaluating the cost of the goods that they were buying. Other aspects such as quality, reliable delivery and customer satisfaction were also being considered by the customers. Although it will be explained in detail later on, one important point worth mentioning here is the reduction of inventory that lean manufacturing brought. Now, OEMs with reduced inventories requested their suppliers to provide shorter lead times and a high level of flexible production. Therefore, first visible change seems to have happened in the workspace layouts. Traditional layouts such as job shops or flow lines were no longer sufficient to meet the capacity requirements. Therefore, manufacturing cells were developed. Cellular manufacturing methods were designed to support high flexibility and incredible throughputs.

On the other hand, lean philosophy also expedited the development of performance measurement systems (Neely, 2005). Most authors agree on a paradigm shift that happened soon after the introduction of lean philosophy (Neely, 2005). Performance measurements not only became more and more popular, but also evolved in terms of their methods. Companies started to measure non-financial data whereas previously most of the measurements were purely based on financial results. However, financial performance results were still important. The change was that now companies were not solely making their decisions based on financials. They were considering other results such as on-time delivery or level of quality.

As a third aspect, lean manufacturing initiated the companies to develop closer relationships with their suppliers. Previously most of the firms were related only at a transactional level. However, this started to shift toward partnerships as lean philosophy spread. In that way, they would be able to gain more competitive advantage and more possibility for cost reductions would be created. It was believed in such a way that both parties would benefit from closer relationship. These kind of collaborative acts triggered information sharing among parties which was the only way to see possible cost reduction areas in networked, dispersed value chains.

1.2 PROBLEM STATEMENT

All these changes that were a result of lean philosophy opened up some new areas in terms of information sharing between companies. In addition to financial data, now the performance measurements were theoretically visible between partners. The case company (Supplier Oy) and its primary customer (Customer Oy, again name kept confidential) were in such a situation. It started with a notification from customer side that on-time-delivery performance was considerably low. However, Supplier's measurement was showing dramatically higher on-time-delivery when compared to Customer's data. Therefore, a mismatch was found between two parties and investigation of the reasons of such mismatch began. Soon after that, it was realized that Supplier's measurement system was more accurate and reliable than Customer's. There were some reasons for such mismatch which will be explained in this thesis. Finally, this brought up the question from customer side on whether they should use supplier's on-time-delivery performance measurement results instead of their own. This would bring Supplier Oy to the point of feeding performance measurements to customer where customer agrees to use supplier's measurements.

1.3 OBJECTIVE

Case company Supplier Oy was in such position that they had the possibility to supply not only products, but also their performance measurement results to its customer. Therefore, the objective of the thesis is…

> *…to introduce a framework that analyzes the novel concept of supplying performance measurements to the customer in addition to sold products, based on the case company and its primary customer.*

This thesis is designed in following way. In Chapter 2, detailed information will be given regarding evolution of workspace layouts followed by lean manufacturing and cellular manufacturing. After that, concept of measurement and performance measurement will be introduced together with their development and evolution. Different performance measurement systems will be analyzed and compared. In addition, insights into how performance measurement systems changed with lean philosophy will be given. In Chapter 4, types of supplier-customer relationships will be explained and the concept of collaboration and its outcomes will be analyzed. After the literature review of those 3 concepts are completed, a framework will be developed and explained step by step incorporating all previous chapters. Framework is based on 3 major dimensions: (1) Lean philosophy, (2) Performance Measurement Systems and (3) Supplier-Customer Relationships. The framework will be elaborated more on how it is related with each of these aspects. In Chapter 6 and 7 case company and its related story will be introduced but thesis will be keeping some information confidential. In Chapter 8, the current process will be explained as well as some forecast on future possibilities. Chapter 9 will contain few discussions based on the performance measurement results with future research implications. Finally in the conclusions part, the correlation between the case and the framework will be shown.

1.4 RESEARCH METHOD AND PROCESS

Case studies are conducted to analyze an idea, a problem, an improvement or a process. These studies often reveal valuable insight into the situation and they can be used as a source of data for future possible studies. Although there are few exceptions, case studies provide good support on theory in the field of management research since they are solely based on real life scenarios.

Gummesson (1993), categorizes data generating methods for management research field as the following:

- Using existing material
- Questionnaires and surveys
- Interviews
- Observation
- Action research (Gummesson, 1993).

First, using existing material contains the usage of anything that has been published before as a source of data. Although the reliability can be questioned sometimes, using existing data is often the easiest way to generate data for research. Second, questionnaires and surveys are sets of questions designed for a target audience. Selection of target audience is as important as the selection of questions. Third, interviews are long discussions conducted with certain selected people and they take a considerable amount of time. Unlike questionnaires, interviews can be less strict and less structured. Observations are watching a certain set of events (a process or a behavior of a certain individual) and they can be done either systematically or free of structure. Systematic observation tends to be more successful since the comparison of the results are highly likely compared to random observations. Finally, action research is defined as the involvement of the researcher in the process, thus shaping and changing it with the research. (Gummesson, 1993).

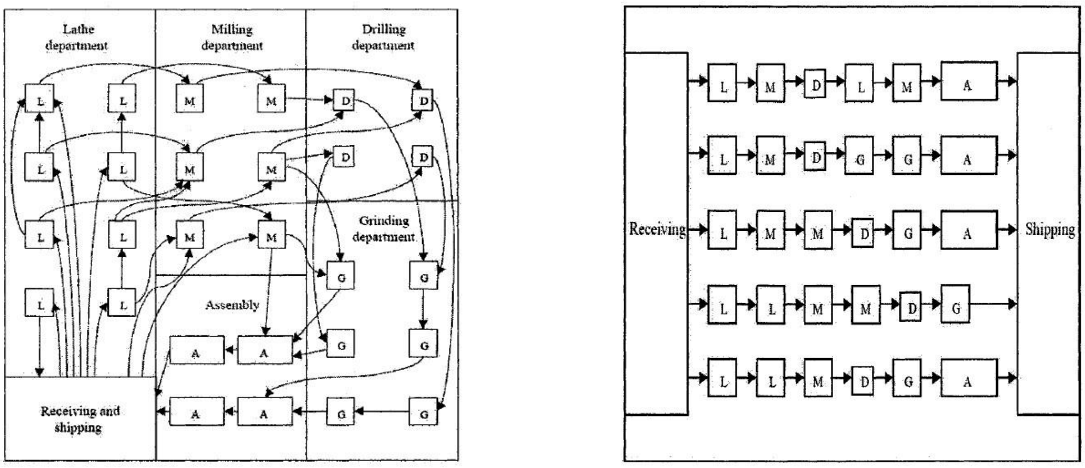
When the data collected in this thesis is considered, it can be categorized under two categories. Primary method is the action research. The author has been involved with the design and development of the case company. Therefore, some changes are initiated by the researcher whereas most of the others are witnessed by him. During the research process, some performance analyses conducted by the author and comparisons were made. This eventually expedited the discussions with the case company's customer and led to sharing performance measurements. Hence, it can be stated that the research is majorly based on action research. Secondarily, observation can also be considered as a source of data at some point. Observations of case company's production and non-interfered analysis of performance measurements can be considered as observations. In Chapter 7 more detailed explanation will be provided in terms of performance measurement results.

2 LEAN MANUFACTURING

Lean manufacturing has become one of the widest accepted manufacturing philosophies around the world. After evolving out of Toyota's just-in-time production method, lean manufacturing or shortly lean spread first to U.S. and then to the rest of the world. Lean manufacturing, aiming to reduce the all types of unnecessary non-value adding activities during the production, brought a lot of changes with it. Workspace layouts were one of the first things that had to change while adopting to lean philosophy. Cellular manufacturing became a key element for lean production since it supported all the flexibility it required. In this chapter different workspace layouts will be introduced followed by giving detailed insights into lean manufacturing. After that, the concept of cellular manufacturing will be explained and compared with traditional workspace layouts.

2.1 TYPES OF WORKSPACE LAYOUTS AND THEIR EVOLUTION

As the manufacturing philosophies evolved, workspaces also changed with them. Traditionally there were two different common types of workspaces. These were job shop type and flow line type as it is shown in Figure 1 below. These two layouts provided good results at their times, nevertheless they failed to meet the current needs with increasing variety of the products. However, they can still be better compared to modern methods depending on the level of product variety required. According to Defersha (2006), today's production techniques had to evolve into cellular manufacturing due to shorter product life cycles, highly customized products and variable demand. These traditional methods were simply not flexible enough to meet those demands. Therefore, firms shifted from mass production of same product to the large product mixes (Defersha, 2006).



Job Shop Manufacturing System Flow Line Manufacturing System

Figure 1. Job shop and flow line manufacturing Systems (Defersha, 2006).

In job shop manufacturing system, every machine is positioned close to each other and grouped together as it can be seen on the left hand side of Figure 1. When the waste in lean philosophy are considered, job shop manufacturing possibly creates a tremendous transport waste due to the unnecessarily complex routing of materials. On the other hand, in flow line manufacturing systems (right hand side in Figure 1), the primary source of waste will possibly be waiting waste since the flow is designed one way only. In flow line systems, each machine has to complete their current product in order to transfer it to the next workstation. In real life balancing each machine is very difficult, due to the fact that they perform different tasks and have different cycle times. Therefore, it will often be the case that one machine will be overloaded whereas all the other machines after that one will stay idle.

Both of the traditional systems discussed above fail to provide the efficiency and the flexibility that lean manufacturing requires. In lean manufacturing variety will be quite high and these systems will not be able to meet that level of variety. Nevertheless, if the batch sizes are big and the product variety is low these configurations still can be better alternatives to cellular manufacturing systems.

2.2 Explaining Lean Philosophy in Detail

Although there are no certain views on how lean manufacturing started, the widest accepted view is that, Taichii Ohno and Shigeo Shingo from Toyota Motor Company systemized the old Ford production and other methods into the system called Toyota Production System or Just-in-Time. Their approach was putting emphasis on inventory. Toyota soon discovered that workers could actually have more to contribute than just muscle power. Also they came up with the result that Ford serial production system was failing when the product types are varying frequently. These developments continued between 1949 and 1975 and it spread to other Japanese companies. After a while, American managers followed Japan and studied this newly developed system which actually is a more flexible application of Ford’s serial assembly lines.

According to Taj (2007), the term “lean” was first used by Womack et. al. (1990) in the book “Machine That Changed the World”. He also adds that lean philosophy was initiated by Toyota to revolutionize the production against mass production (Taj, 2008). During World War II, Ford Motor Company had initiated the first steps of lean production but it was Japanese automobile manufacturers who saw the potential in this philosophy and continued to develop this. According to Puvanasvaran et. al. (2009) during that time many organizations acquired lean manufacturing to gain competitive advantage against their competitors during economic slowdown (Puvanasvaran et al., 2009).

Taj (2007) explains the diffusion of lean philosophy as the following. In the late 1970s, Chinese manufacturers adopted to lean and with the help of Taichii Ohno, the inventor of lean philosophy. Their First Automotive Works (FAW) plant was a Soviet funded automobile manufacturing company and Taichii Ohno was helping them to have a better understanding on how to change the layouts in production for different products, thereby reducing waste. Chinese engineers liked the idea and travelled frequently to Japan and learnt this manufacturing philosophy deeply. During 1990s many companies in Europe and USA were eager to follow lean manufacturing philosophy and they tried to build cellular manufacturing systems as they learnt from Far East countries (Taj, 2008). Although it seems to be so that lean manufacturing is an automotive industry originated idea, it made its way throughout all different types of industries and today it is one of the widely accepted manufacturing methods in the world.

Lean philosophy can be seen as a broadened view of Ford’s manufacturing philosophy with variety. The main idea is considered as minimizing all possible waste (“muda” in Japanese) in all areas. Chauhan (2012) explains the aim of lean manufacturing philosophy as spend less human effort, operate with less inventory and less space, spending less time to develop newer products, and being highly responsive to varying customer demand. She also adds that one of the aims of lean includes ensuring high quality with the most economically efficient ways (Chauhan & Singh, 2012). The competitive advantage that lean provides is based on cost reduction in without losing from quality and delivery performance. Therefore, it is quite understandable why this philosophy has become so popular. Lean philosophy is based on three main aspects which are:

- Elimination of waste (muda)
- Minimizing workforce
- Optimization of flows

However, it should be noted that the latter two aspects are eventually related with the first item. Waste or muda can be defined as any kind of activity that does not add anything to final customer value hence causing unnecessary costs. With the identification and reduction of these waste in various areas certainly reduces the costs and provides operational efficiency. Hajek (2009), defines seven types of waste that lean manufacturing aims to reduce. These are:

- Transport
- Inventory
- Motion
- Waiting
- Over-processing
- Overproduction
- Defects (Hajek, 2009).

First, transport waste is generated from the movement of materials inside the manufacturing area. This could be the transfer of materials from the main warehouse or between workstations. In both cases transportation of goods add no value to the customer, hence they are the first source of waste. Relatively the time is lost for transporting the goods, where in fact it could have been spent on actual production. Therefore, transportation of the goods inside plants has to be analyzed and optimized in order to minimize the duration of transportation. Rearranging the inventory can also be a good solution for minimizing this waste since there is often considerable amount of time spent for looking for the raw materials inside the stock area.

Second, inventory waste is the most famous type of waste in lean thinking. Excess inventories drive up the costs in terms of handling and space requirements. Also large inventories require more people to handle meaning more salaries. Therefore, excessive inventory is seen as an important waste that has to be reduced as well. However, again according to Hajek (2009), there are two things that make companies tend to keep larger inventory than they should. One is the volume pricing. When the raw material purchases are made in larger quantities unit prices are expected to be lower. Therefore it has to be analyzed carefully if it is favorable for the firm to reduce their inventories and purchase volumes. The other issue is that inventory is considered as an asset on balance sheet. Reducing the inventory rapidly may give a wrong impression in financial terms. This may cause financial directors to be against the lowering the inventories. For this problem, inventories must be reduced together with the liabilities step by step (Hajek, 2009).

Third, motion waste consists of all unnecessary movement of the operators or the machines. In today's world where each second is important in terms of cycle time, this aspect has to be considered and optimized as well. As mentioned above, during first stages of lean philosophy a lot of companies from USA and Europe started to implement lean manufacturing by building manufacturing cells. Today as it is known, cellular manufacturing is an essential tool of lean philosophy. Therefore, all the unnecessary movements of the operators have to be eliminated since they are not adding any value to production. A better way of preventing this waste is to optimize it during the design stage. It is obvious that it could be more difficult and expensive to change the structure of workstations after they are already set up.

Fourth, waiting waste is the idle time of either the operators or the machines. As it will be explained later, in lean philosophy machine utilization rate is an important metric to measure productivity. Shambu et. al. (1996) defines this machine utilization rate as operational time divided by total time (Shambu et al., 1996). When a machine is waiting for the raw material or the Work-in-process (WIP) material from other workstations, it can be considered that it is losing from its productivity. In order to prevent the waiting waste, material flows inside the plants have to be examined and optimized. Flexible routing option is a good way to handle these waiting times. When a machine is waiting for a component and the other one has excessive WIP material waiting in front of it, it is a wise decision to shift some of the workload from one workstation to the other one.

Fifth, over-processing is explained as a consequence of poor design of the product and the processes. When a new product is designed, designers must always consider the complexity of the production stages and try to modify the design so that these stages are simplified. Tools that are used in the production can also be a source of over-processing. For example, slow computers, poor quality equipment also increases cycle time and create over-processing waste.

Sixth, overproduction originates from the misbalance between production and the demand. It can also lead to excessive inventory (inventory waste) because the finished goods also occupy the inventory space. In lean philosophy this is usually prevented by using pull type of production instead of traditional push type. In traditional manufacturing (push type), firms were producing well in advance and keeping buffer stocks to answer the changing demands of their customers. On the other hand pull type production requires that production is initiated only when the customer orders an item. However, following pull type of production requires high level of flexibility in production to react to the changing demands of their customers. If the situation is not controlled precisely, late deliveries can occur immediately leading to customer dissatisfaction.

Seventh, defects are considered as a waste because they often lead to rework or reclamation. When an item is produced with defects, it has to be corrected or has to be done all from the beginning depending on the process. Therefore, different mechanisms that will be explained later are developed in order to prevent defects while achieving both high quality and operational excellence in production. In addition, a defect may cause the product to become scrap and increase the unnecessary material consumption. This definitely increases the operating costs of the factories (Hajek, 2009).

All these wastes explained above are driving up the costs in operations and causing the productivity rate to drop down. Therefore, lean philosophy appliers always look for different areas to reduce these wastes and try to achieve cost benefits. It should also be added here that in some context, there might be one or two more wastes added to this list such as waste of creativity or waste of resources (electricity, water…etc).

It is essential for lean philosophy to improve processes which will improve the results eventually. Chauhan (2012), claims that lean puts emphasis in teamwork, continuous training and development, pull production, cellular flow and quick adaptation to changing batches (Chauhan & Singh, 2012). For these purposes some important management systems are developed. Howell (2009) summarizes the most common tools as the following:

- 5S programs
- Quick changeover techniques
- Just-in-time production
- Total productive maintenance (TPM)
- Mistake proofing (Poka-yoke) (Howell, 2009).

First, 5S programs are a common tool for designing workspace and it states how a workspace must be operated in accordance with lean philosophy. As claimed by Ho (2010), Table 1 below explains the five aspects of a working space. The names are originally in Japanese however they are converted to English as well.

Table 1. 5S Program (Ho, 2010).

Attribute	Explanation
Sort (Seiri)	Elimination of unnecessary items from the working space. All broken items and useless tools must be cleared away from the workspace
Set in order (Seiton)	Accessing everything easily when needed. Item can be a tool, a component or even a document. This makes the operator more acquainted with his environment
Shine (Seiso)	Performing daily cleaning of the working area. This also makes the workers more aware of the needs for action when problems arise
Standardize (Seiketsu)	This is achieved through the participation of all workers. Workspaces must be designed according to a standard so that workers can be familiar with all different workstations
Sustain (Shitsuke)	Prevention from going back to old traditional methods. Periodical inspection may be necessary

Second, quick changeover techniques are another aspects of lean philosophy. Quick changeover of the tools and machine components and materials enables the company to be flexible against volatile demand. When the variety is high and the batch sizes are low, it can be estimated that there will be frequent need to modify workspace in order to produce different components. Implementing different techniques and innovations that cuts down on the changeover time is crucial for improving productivity.

Third, just-in-time production can be explained as delivering right things, at right time, at proper quality and quantities. As it is explained above that lean philosophy originated from just-in-time principles. Therefore, just-in-time production enables firms to reduce their WIP inventory without sacrificing on quality and delivery performance. However, it requires precise production planning and control over supply chain network.

Fourth, Jostes and Helms (1994) describes total productive maintenance (TPM) as a comprehensive relationship among whole organization, particularly between production and maintenance. Operators and maintenance technicians share their experiences for the purpose of providing better quality and shorten the machine down-time (Jostes & Helms, 1994). Occasionally operators are also responsible for performing maintenance on the machines that they use. In that case the expectation is that they should share their knowledge about the machines or how to perform maintenance to raise the awareness and knowledge of all operational team.

Finally, mistake proofing (Poka-yoke) is also an accepted technique that aims to make operators work with minimal amount of mistake. Poka-yoke simply consists of modification of process or usage of additional tools that makes the process impossible to advance with mistakes. An industrial engineer at Toyota named Shigeo Shingo first introduced poka-yoke. Shingo's technique consists of integrating small devices into various production steps to prevent human or machine error. Shingo (1986), states that mistake and defect are two different things. Mistakes are inevitable and a result of human nature, since it cannot be expected for anyone to concentrate 100% on the work he is performing. However, if a mistake reaches to a customer, it is considered as a defect. Therefore, mistakes are clearly avoidable. Therefore, poka-yoke aims to change the manufacturing processes in a way that a mistake now becomes (1) impossible to make, (2) very easy to spot and fix (Shingo, 1986). According to Fisher (1999), poka-yoke mainly aims to remove the cause that creates the possibility for defective production operation. Optionally, inspection may come afterwards (Fisher, 1999).

There are definitely more techniques than those five mentioned above. However, these are the ones that are considered to be most popular and hence have the broadest applicability to different industries. All these techniques are just tools to follow lean manufacturing, hence following lean philosophy will not necessarily be achieved only by applying these techniques mentioned above.

2.3 CELLULAR MANUFACTURING

The complexity of products and processes required to manufacture them have increased a lot over the last decade. Customers have shifted from purchasing big batches of same products to customized items of smaller quantities. Klippel et. al. (1999) gives a detailed explanation to this phenomena. Firms now have difficulty in maintaining huge stocks because of two possible reasons: (1) increased costs, (2) risk of obsolescence. Therefore, they are eager to manufacture in smaller lots to mitigate these risks. However, manufacturing in smaller lots brings few problems which are:

- Inefficiency of system
- Lower quality
- Lower productivity
- Increased costs

In order not to experience these problems, group technology was developed (Klippel et al., 1999). Again according to Klippel et. al. (1999), the term group technology was first used in 1950s by Mitrofanov. The aim was to exploit the similarities of manufactured parts in order to gain economical advantage. Group technology is a proper way to deal with high variety and low demand (Klippel et al., 1999).

Cellular manufacturing is considered to be an application of group technology (Elleuch et al., 2008). According to Aghazadeh et. al. (2011), first idea of work-cells and cellular manufacturing goes back to 1920s (Aghazadeh et al., 2011). In cellular manufacturing machines of different types are arranged and grouped together to form the cells. Then each group (cell) is allocated for the production of a certain part families with certain similarities. In other words, cellular manufacturing brings the advantages of job shop and flow line systems together (Klippel et al., 1999). Kumar and Hadjinicola (1993) defines cellular manufacturing as, production of similar products that require similar processes using dissimilar machines that are arranged in close physical proximity (Kumar & Hadjinicola, 1993). This is the opposite of job shop layout where same machines are grouped together to form a "functional layout" (Elleuch et al., 2008). Hyer et. al. (1999) as cited in Yazici (2004) explains that, in cellular manufacturing operators and work tasks are connected in terms of time space and information.

When cellular manufacturing is compared with traditional methods, it certainly has a lot of advantages among with conditional disadvantages. In literature there is a conflicting view on whether manufacturing cells are an ultimate solution to producing high variety products or not. Considering the opinions of authors regarding this matter, the advantages of cellular manufacturing can be summarized as the following:

- Reduced work-in-progress (WIP) inventory
- Reduced set-up times
- Less material handling costs
- Higher throughput rates
- Reduced materials movement
- Increased utilization rate
- Fast response to product change
- Decreased production flow time
- Increased quality (Kumar & Hadjinicola, 1993; Elleuch et al., 2008; Yang & Deane, 1996)

When we try to link the advantages of cellular manufacturing with the lean philosophy, it can be understood that each benefit corresponds to at least one aspect in lean manufacturing. According to this, Table 2 can be constructed to illustrate the connection between the benefits of cellular manufacturing and lean philosophy.

Table 2. Benefits of cellular manufacturing versus lean philosophy elements.

Benefit / Lean Element	Waste reduction	Optimization of flow	Quick tools changeover	Just-in-time production	Mistake proofing
Reduced WIP inventory	x				
Reduced set-up times			x		
Less material handling costs	x	x			
Higher throughput rates	x			x	
Reduced materials movement	x	x			
Increased utilization	x		x	x	
Fast response to product change			x	x	
Decreased production flow time	x		x	x	
Increased quality					x

As it is seen in Table 2, there is certain correlation between benefits of cellular manufacturing and lean philosophy elements. Therefore, it can be concluded that cellular manufacturing seems to be a suitable method for manufacturing with lean philosophy. However, there are few problems of manufacturing cells depending on the situation as well.

According to a research conducted by Dale and Russell (1983) as cited in Marsh et. al. (1997), some major problems with cellular manufacturing are the following:

- Load balancing between cells
- Inability to analyze capacity and loads of the cells
- The occasional need to share key machines between cells
- Slow decrease in system discipline
- Part mix change slows down manufacturing and causes imbalances (Marsh et al., 1997).

In addition to these, Yazici (2004) argues that cellular manufacturing does not possess universal superiority over functional systems (Yazici, 2005). Another important aspect is that since no two machines are identical in a cell, any possible breakdown stops the whole cell from production. This may lead to increased cost of operation and cost of maintenance as well as late deliveries and customer dissatisfaction.(Elleuch et al., 2008).

2.4 DESIGN PROCESS OF A MANUFACTURING CELL AND FLEXIBILITY CONCEPT

Designing a manufacturing cell is a complex process and requires precise analysis. It is often difficult to estimate the performance outcomes of individual design decisions when building a cell. In addition, the large number of varying parameters make mathematical modeling highly difficult (Aurrecoechea et al., 1994). Most of the time heuristics is the key driver for designing a manufacturing cell. Yang et. al. (1996) also points out that most design factors are ignored during the initial design phase (Yang & Deane, 1996).

According to Prickett (1994), there are three main phases of a manufacturing cell design process.

- System design
- System control
- System integration

First, designing phase consists of understanding which parts or part families will be allocated to each cell. This is generally grouping similar products into identifiable families. (Prickett, 1994) Then the size of the cell versus part mix size is an important factor that must be considered. This means whether there should be one big cell or smaller but many cells (Yang & Deane, 1996). Furthermore, Yang et. al. (1996) also states three main design decisions which are: (1) number of cells to establish, (2) the machine constituting in each cell, (3) the part families assigned to each cell (Yang & Deane, 1996). After this, design process is continued with assigning workers to each cell. Time required for this design process can be highly significant, therefore it is important to begin this stage well in advance to actual production (Johnson & Wemmerlöv, 2004).

Second phase can be explained as the design phase of cell control systems such as availability of material, processing times and labor time. Prickett (1994) states that a well designed performance monitoring system is crucial for development of the cell (Prickett, 1994). Some authors are in favor of pilot studies and computer simulation, meaning that before starting production some numerical tests has to be carried out for a more successful implementation (Aurrecoechea et al., 1994). On the other hand, some authors such as Klippel et. al. (1999) claim that majority of mathematical algorithms and models lack practicality and do not reflect reality (Klippel et al., 1999). In addition, Yang and Deane (1996) also states that simpler mathematical models fail as well, since they consider the operation of the cell in a perfect environment such as no setup times and continuous flow (Yang & Deane, 1996).

Third phase is the actual implementation of the cell. Regardless of the previous two stages constant performance monitoring is essential after this stage in order to get the desired throughput from the cells. It is thought of high importance that adaptation to changing environment is crucial for the cellular manufacturing. In addition to that, cell implementation may fail in the last stage if the performance of current manufacturing seems to be sufficient (Johnson & Wemmerlöv, 2004). Involvement of workers in cell design and training are two important factors that should not be under estimated (Prickett, 1994).

As the methods of production changed over time, the concept of flexibility also became more important. Yazici (2005) defines flexibility as an adaptive response to changes in customer behavior and external environment and uncertainties (Yazici, 2005). In addition, according to Gerwin (1993), Narasimhan and Das (1999) and Soliman and Youssef (2001) all as cited in Yazici (2005), flexibility is closely associated with advanced manufacturing techniques recently (Yazici, 2005).

Now that it is known, cellular manufacturing can be considered as an advanced manufacturing technique. Therefore, flexibility attribute is quite important in cellular manufacturing as well. Kannan and Ghosh (1996) claims that when the demand is volatile cellular manufacturing may yield to poorer performance (Kannan & Ghosh, 1996). Hence, flexibility and adaptation to changing demand is highly crucial in cellular manufacturing technique as well.

Flexibility can be defined depending on the situation. However, basically there are four types of flexibility. These are:

- Volume
- Delivery
- Mix
- New product flexibility (Yazici, 2005).

First, volume flexibility corresponds to the ability to respond to changes in customer demands. Johnson and Wemmerlöv (2004) claims that demand instability may cause cells to be unequally balanced, hence resulting in a loss of capacity (Johnson & Wemmerlöv, 2004). Also, demand pattern has a great effect on performance of the cells. Stable demand pattern yields in lower set-up frequency and lower complexity in production planning and job scheduling (Kannan & Ghosh, 1996). Since there is no one size fits all type of job scheduling criteria, complexity in production planning can take serious amount of time when the demand volatility is higher (Mitchell & Spurgeon, 1991).

Second, delivery flexibility means that being able to adapt to the cases of changes in the requested delivery date. Although, suppliers are not expected to change their forecasted delivery dates after the confirmation of orders, this may be required in some cases of close supplier customer relationships.

Third, mix flexibility is the rate of adaptation to answer changes in the product mixes. Lot sizes are known to affect the flow time in cellular manufacturing due to the increased number of set-ups of the machines (Shambu et al., 1996). Smaller lots of same product and the more mixed the products are, more instances of machine set-ups are expected. In addition to this, Kannan and Ghosh (1996) explains that increased variety in product mixes increases the frequency of set-ups and possibly results in two things: (1) reduction in capacity, (2) increased batch sizes and buffer inventory (Kannan & Ghosh, 1996). Also part mix change slows down manufacturing and causes imbalances between manufacturing cells (Marsh et al., 1997). Therefore, reduction in set-up times such as fast set-up and quick changeover tools are crucial in this sense.

Finally, new product flexibility can be explained as the ability to implement new products into ERP systems and eventually production easily. Whenever there is a new product or product family, flexible firms must be able to adjust their production to produce these items without sacrificing on the delivery performance.

In addition to these four categories of flexibility, there can be many more aspects defined as flexibility. Labor flexibility is also defined as a critical aspect on manufacturing cell performances. Labor scheduling and labor transfer is known to affect overall performance of the cells. Flexible assigning of the workers between cells and worker transfer between cells are two common solutions to achieve better throughput in working cells (Shambu et al., 1996; Elleuch et al., 2008). Prickett (1994) also states that worker transferring option between cells enables flexible production (Prickett, 1994). Since permanent machine and worker dedication results in poor flow due to queue related issues, labor flexibility is also important in this sense (Kannan & Ghosh, 1996).

Furthermore, routing flexibility is also accepted to be important and increases lead time performance (Yazici, 2005). As it is explained before since no two machines are identical in a cell, any possible breakdown on one of the machines prevents the whole cell from producing. According to Elleuch et. al. (2008), most of the research done on cellular manufacturing did not consider the possibilities of cell breakdowns. Inter-cellular transfer is a common solution policy and external routing flexibility is also defined in situations of breakdowns (Elleuch et al., 2008). One way to analyze routing and inter-cellular transfer scenarios is to use mathematical models. According to Chen (2001) and Onwubolu (1998), math models are often used for production planning problems when product or demand structures get too complex. These models have wide applicability and most of them focus on job sequencing, scheduling and alternative routing options. However, heuristics are also generally used when math models get too complex and these math models fail to consider production flexibility (Chen, 2001; Onwubolu, 1998). On the other hand, Klippel et. al. (1999) argues that most of the mathematical models lack practicality and applicability (Klippel et al., 1999).

Equipment reliability is crucial in cellular manufacturing (Johnson & Wemmerlöv, 2004). Therefore, maintenance is of high importance in cellular manufacturing. Elleuch et. al (2008) defines two solutions to cope with breakdowns which are:

- Preventive maintenance
- Reducing the severity of breakdown

First, preventive maintenance is all kinds of periodical maintenance that is performed regularly on every machine in the cell. Although each machine requires different frequencies of maintenance, it must be always kept in mind that effective maintenance improves cell performance in overall. Second, reducing the severity of breakdowns consists of solutions such as producing in redundancy and having intermediate buffer stocks as well as re-routing flexibility (Elleuch et al., 2008).

Change towards lean manufacturing majorly influenced the workspace layouts, because all the traditional methods were not sufficient to support the flexibility required by lean philosophy. Figure 2 below tries to illustrate these changes and summarizes Chapter 1.

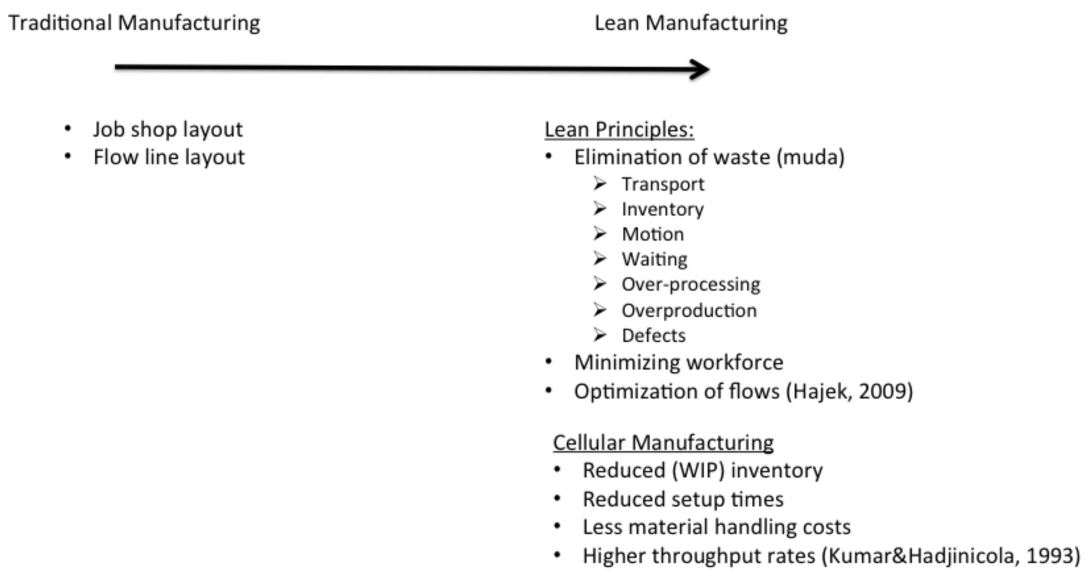


Figure 2. Changing towards lean manufacturing.

In Chapter 1, different historical workspace layouts and their evolution throughout time were introduced. Traditionally, job shop and flow line layouts were the two main configurations. Lean production which mainly focuses on the aspects of elimination of non-value-added activities (waste or muda) started to become popular globally in late 1980s. With the development of lean manufacturing philosophy, a new type of workspace layout was required to support lean production mainly in terms of flexibility and high variety in the product range. The cellular manufacturing techniques were developed in this purpose that was correlating with the lean's primary idea of minimization of waste (muda). As it can be seen in Figure 2, cellular manufacturing brought some benefits such as reduced WIP inventory, reduced material handling and movement, higher throughput rates and so on. Also, some tools were developed to support the lean operations. 5S programs, Quick changeover and Poka-yoke are few of these tools. However, there are lot of elements to consider while designing and implementing cellular manufacturing. In fact, they have to be analyzed and evaluated precisely to benefit from cellular manufacturing as intended. In the next chapter concept of performance measurement will be explained and the evolution of performance measurement systems will be analyzed.

3 PERFORMANCE MEASUREMENT SYSTEMS

Change towards lean manufacturing required more than just changing the workspace layouts. It was a shift of holistic management philosophy. Thus it required a change in many areas. Measuring the performance has also changed with lean manufacturing philosophy. In this chapter the concept of performance measurement will be introduced, its fundamentals will be explained and the changes in performance measurement systems will be analyzed.

3.1 CONCEPT OF MEASUREMENT

Measurement as a concept can be defined as quantifying something in terms of chosen units. From perspective of business terms, it can be explained as judging the quality, effect or value of something[1]. Measurements are necessary almost everywhere to make logical decisions. It must be remembered that all the measurements have errors to some extent. However, smaller errors are supposed to yield more successful decision making since they reflect reality more.

When it comes to evaluating the success of measurements, there are two widely accepted key attributes. These are:

- Reliability
- Validity

First, reliability is used to define the repetitiveness correlation of the result that a performance measuring system gives under same or similar conditions. In other words it tells how precise a performance measurement system is. Suomala et. al. (2007) states that reliability is context independent, meaning that measuring should give same results regardless of the case that it is used in. Validity on the other hand is the accuracy of the measurement. It can be explained as the measure's correlation with the concept that is to be represented. Validity is highly context dependent since it is the suitability of the measure being used in that specific case (Wenning, n.d.). Figure 3 visualizes the concepts of reliability and validity by using an analogy of target shooting.

[1] Cambridge Online Dictionary, Available at: http://dictionary.cambridge.org/dictionary/business-english/measure_1?q=measuring

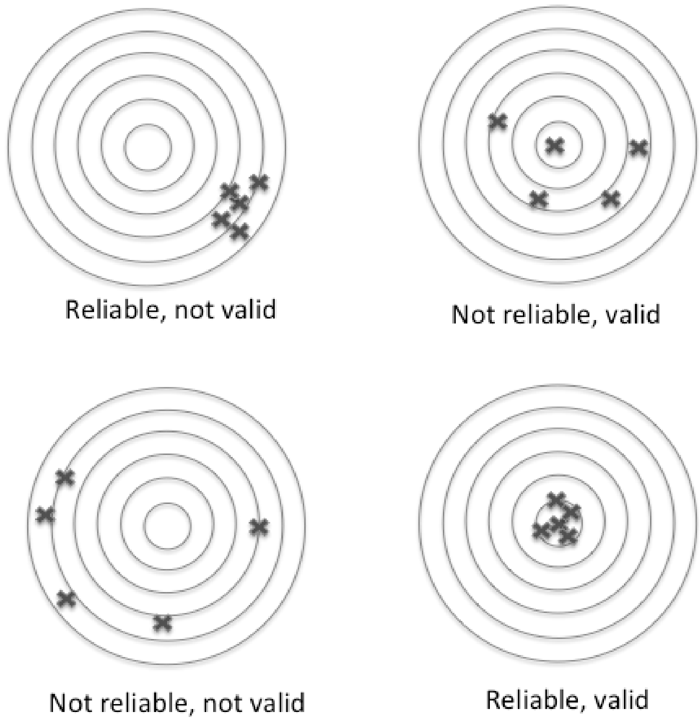


Figure 3. Visualization of reliability vs validity (Wenning, n.d.)

In Figure 3 above, four possible scenarios are illustrated based on reliability and validity. Even though there are few more aspects such as relevance or feasibility, reliability and validity (in other words precision and accuracy) are the most crucial ones while evaluating the success of measuring. Another point to mention here is that no measurement can be 100% correct. There is always room for error in measurements. However, the important aspect is to define a feasible error tolerance and make sure that the measurements are within that defined tolerance range.

3.2 DEFINING PERFORMANCE MEASUREMENT

Performance measuring is basically a set of activities that help managers to analyze their current situation and make decisions accordingly. Different authors define performance measuring differently. Hoverstadt et. al. (2007) defines performance measuring as monitoring “in real time” the metrics which are relevant and necessary for successful operations of organizations (Hoverstadt et al., 2007). However, Ghalayini and Noble (1996) claim that performance measuring is used to analyze, control and improve manufacturing activities that makes sure that objectives and goals are realized. In addition to this performance measuring can also be used to compare different firms, plants, divisions, teams or individuals (Ghalayini & Noble, 1996).

Historically, the idea of measuring performance became famous in 1950s (van Schalkwyk, 1998). Firms wanted to know and evaluate how they are performing and they started to use some of their internal information for this purpose. Nevertheless performance measuring has evolved a lot with the ever-changing manufacturing methods. Most of the authors agree on a shift in performance measuring around late 1980s (Ghalayini & Noble, 1996; Najmi et al., 2005; Upton, 1998; Neely, 2005).

Although it is possible to classify performance measurement by either traditional or modern, other classifications are also possible. According to Parker (2000), there are four types of performance measurement methods and firms often use at least three of them. These are:

- Outcome measures
- Action measures
- Input measures
- Diagnostic measures

First, outcome measures consist of observing the selected outputs over the time and making sense out of the numbers. Obviously, this will be a lagging indicator since outputs always reflect past performance. Traditional methods that used financial metrics are perfect examples of this type of measurement. They only considered financial reports which was a indication of the past. Therefore it was not helpful anymore to deal with this amount of delay, while they were seeking for options to make rapid decision making.

Second, action measures are explained as measuring the activities that create the outputs. For instance, measuring the process steps or any indirect activity individually can be a good indication of the performance. Measuring cycle time can be a good indication of production capacity most of the time. These type of measures are considered as leading rather than lagging, since they change in real time and provide valuable information for decision making. Modern type of performance measurement systems can be classified in this category.

Third, input measures can be defined as analyzing the amount of inputs allocated for an activity such as calculation of labor cost or raw material. These type of measures are considered to be useful only for control processes. Another drawback is they are not meaningful by themselves, they have to be compared with output measures while analyzing the performance. This certainly makes them a lagging indicator as well. Finally, diagnostic measures aims to explain why the output is at that current level by analyzing each action or input individually and comparing it with the overall output. Depending on the case they can be leading or lagging (Parker, 2000).
With the information provided above, it is now possible to categorize performance measurement in other two different aspects, which are:

- Financial measures
- Non-financial measures

Financial measures correspond to all measurement that are related with cash flow of the company such as return on investment (ROI) or return on assets (ROA). They are obviously very important reflection of the companies' performance, since the ultimate goal of enterprises is to make profit with their operations. On the other hand, non-financial measures can be explained as all other metrics that are not directly related with monetary implications such as customer satisfaction, level of quality or on-time-delivery. By their nature, these are more difficult to quantify and measure.

In this sense, financial metrics will conflict with the lean philosophy and lean companies are more likely to use non-financial metrics while evaluating their performances (Upton, 1998; Åhlström & Karlsson, 1996). Figure 4 below illustrates how financial metrics are lagging and not suitable for rapid decision making process.

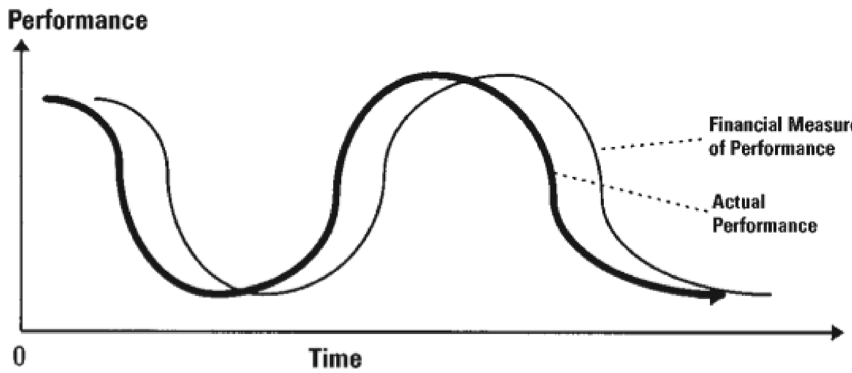


Figure 4. Delay between financial measures of performance and actual performance (van Schalkwyk, 1998).

As it can be seen in Figure 4, there are two different effects of a performance measurement lag. First one is when actual performance is higher than measured performance. This may lead organizations to question their performances at wrong times although everything may have been going as desired. Any possible action taken during these times may prevent firms from achieving their objectives, without even they know about it. Second aspect is that actual performance may be lower than indicated performance. In my opinion, this is more dangerous than the previous one, since it will lead organizations to overestimate their performance and may result in a catastrophe. In both cases, the time delay between the measures and actual performance is vital, because it directly affects the decision making processes.

On the other hand, it can be possible to see a correlation between financial and non-financial measures. For instance, a company making reliable deliveries and has a good level of customer satisfaction is easily expected to have strong financial metrics as well or vice versa. However, exceptions are always possible such as a highly profitable company might be suffering from low quality in their products, when the competition in their market is very weak. Also financial metrics themselves do not reveal the areas of improvement (i.e. productivity). Therefore, both aspects have to be considered when conducting performance measurements. This way successful decision making can be ensured.

3.3 PERFORMANCE MEASUREMENT SYSTEMS

Performance measurement system (PMS) can be defined as a set of performance measurements that serve as a basis for decision making. From the perspective of one author, performance measurement systems (PMS), can be explained as collecting data and using it in decision making process and taking action accordingly (van Schalkwyk, 1998). Powell (2004) considers performance measurement systems from a holistic system viewpoint that acts as a roadmap for guidance (Powell, 2004). Mostly, performance measurement systems are context dependent, which means that each firm should develop their own PMS to serve their needs. For instance, one performance measurement (metric) can be very useful and critical for one firm, whereas it might be completely irrelevant for some other firm.

Building up a performance measurement system can be a challenging task in most of the cases. First difficulty starts while deciding what to measure, because deciding what to measure is harder than it seems. If companies want to measure everything, most likely they will end up with wasting a tremendous amount of resources. Parker (2000) defines “measuring span” as the items that are subjected to measure. Measuring span has to be chosen very carefully and reviewed periodically in order to avoid waste of resources (Parker, 2000).

According to Parker (2000), van Schalkwyk (1998) and Ghalayini and Noble (1996), traditional performance measurements were based heavily on financial data and management accounting systems were used to evaluate the performance of the companies (Parker, 2000; van Schalkwyk, 1998; Ghalayini & Noble, 1996). Financial metrics such as profit margin or return on investment (ROI) were used to analyze the operations of firms. According to Ghalayini & Noble (1996), productivity was one of the most important metrics while evaluating the performance and they define three different forms of productivity that firms frequently analyzed. These are:

- Partial productivity
- Total factory productivity
- Total productivity

First, partial productivity is the ratio of total output to one class of input. For a manufacturing firm, an example can be given as total number of products per year divided by number of hours of operation. Second, total factory productivity can be defined as the ratio of total output to sum of associated capital or labor. Return on investment is a close example to this ratio. Finally, total productivity is explained as the ratio of total output divided by total input. This considers all the other activities of the firm regardless of direct involvement with the manufacturing (Ghalayini & Noble, 1996).

Using financial data was helpful at that times, however after 1980s world market started to evolve. Requirements shifted from low cost production to other aspects such as quality, flexibility, lead time and reliable delivery (Ghalayini & Noble, 1996). Manufacturing systems also changed with these requirements and changing manufacturing systems required changing in information as well (Upton, 1998). Therefore, these traditional methods which relied heavily on financial data failed to assess the modern manufacturing techniques. Parker (2000) explain that, although financial data were always objective and precise these traditional methods failed for three reasons:

1. Financial data was mostly considering internal environment of the firm and not reliable and applicable when compared with other firms' financial metrics
2. It was impossible to financially quantify some factors such as quality or customer satisfaction
3. They were based on past data and for that reason they were lagging heavily. It did not provide reliable information to make predictions for future operations hence not helping in decision making process (Parker, 2000).

In addition to these, different authors add their comments why these traditional financial metrics failed to adapt to the changes in manufacturing methods. Najmi et. al. (2005) states that traditional methods failed to define and prioritize firms' strategies as well as they did not have ability to change. Their primary weakness was based on evaluating past performance (Najmi et al., 2005). Van Schalkwyk (1998) adds that traditional metrics provided infrequent and aggregated information with a top-down approach. This top-down approach put too much burden on top level managers and prevented them from rapid decision making. Also, the biggest problem was that these financial methods did not consider client needs and meeting customer requirements (van Schalkwyk, 1998). Ghalayini and Noble (1996) claim their viewpoint on the weaknesses of traditional methods as the following. Financial reports were mainly lagging and vulnerable to manipulation. Furthermore, there were too much effort that had to be spent to mine and analyze financial data frequently. It obviously was not possible to quantify some aspects in financial numbers such as flexibility or on time delivery performance (Ghalayini & Noble, 1996).

The weaknesses of the traditional, finance-based performance measuring systems can be summarized as the following with the literature review that is done above.

- Lagging reports
- Considering only internal environment
- Impossibility to financially quantify some factors (i.e. flexibility, customer satisfaction)
- Inability to change
- Not considering firms' strategies and objectives
- Not considering customer requirements
- Possibility of manipulation
- Too much effort to mine and analyze data
- Redundant, outdated data for managers (Neely, 2005).
- Focused only on low cost production and high labour and machine utilization

Due to the reasons given above, traditional, finance-based performance measurement systems were failed to meet the demands of ever-changing business environment. Therefore, PMSs had to evolve in order to make the decision making processes more accurate. In the next chapter, this evolution process will be explained and some information will be given regarding how a modern performance measurement system should be designed.

3.4 EVOLUTION AND FUNDAMENTALS OF PERFORMANCE MEASUREMENT SYSTEMS

As the manufacturing systems evolved in late 1980s, performance measurement systems changed along with them. After 1980s world marked changed in a way that customers demanded quality, flexibility, reliable delivery and shorter lead times; rather than only low cost products. Also, the concept of performance measurement began to draw more attention as it can be proven by the number of publications. Neely et. al. (2005) investigated this phenomena with a bibliographic research of number of publications that had the phrase "Performance measurement" in the title over the years. Figure 5 below illustrates the year versus the number of publications.

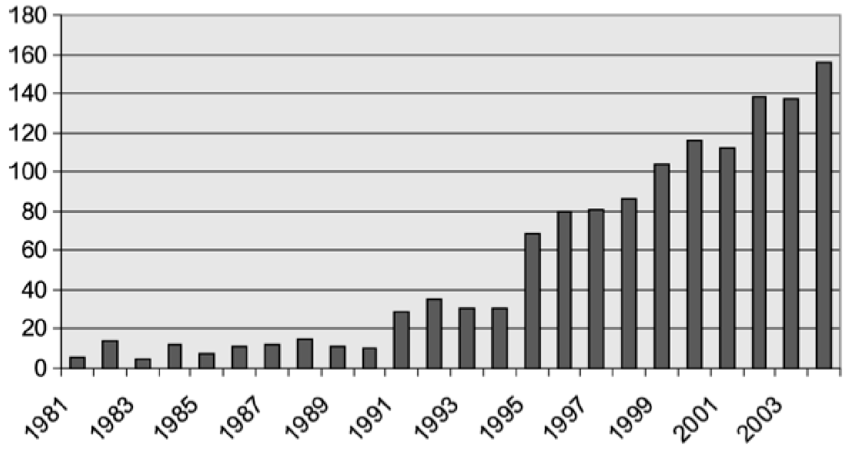


Figure 5. Number of publications with the topic of "Performance Measurement" over the years (Neely, 2005).

As it can be seen in Figure 5, starting from 1990s the number of publications started to increase rapidly. This corresponds with the previous statement that claims manufacturing systems evolved in late 1980s. Throughout the 1980s, this change in manufacturing methods enforced organizations to re-evaluate and adjust their performance measurement methods. Lot of authors developed frameworks to answer this need. However, not all of them were applicable or easy to implement. According to Bititci et. al. (2000), some of these frameworks became more popular than the others (Bititci et al., 2000). It would be wise to mention about these frameworks and their weaknesses as well at this point. These frameworks can be stated as the following with their developers and year of introduction.

- Balanced scorecard (Kaplan and Norton, 1996)
- SMART (Strategic Measurement Analysis and Reporting Technique, Cross and Lynch, 1988, 1999)
- Performance Measurement Questionnaire (Dixon et. al., 1990)
- Performance Criteria System (Globerson, 1996)
- Performance measurement for world class manufacturer (Maskel, 1989)
- Cambridge performance measurement design process (Neely. et. al., 1995)
- Integrated performance systems reference model (Bititci and Carrie, 1998)

Although the examples can be continued, these are the ones that became more known and accepted than the others. Instead of explaining all of them one by one, it would be plausible to look at some of them and highlight the differences with the traditional methods. A comparison among them is also possible to make to give some more information about their weaknesses.

First, balanced scorecard is an performance evaluation method that can measure the performance systematically and it is widely accepted as a reliable performance measurement system. Kaplan and Norton (1992), aimed to provide a simple and powerful tool to managers to analyze their performance at a glance. Balanced scorecard evaluates performance from four different aspects which are:

- Financial perspective
- Internal business perspective
- Innovation and learning perspective
- Customer perspective

In each of these perspectives, there is a constructed table that associates goals with measures. Therefore, it was designed to align companies' strategies and objectives with their current performance measurements. Therefore instead of sub-optimizing the measures, balanced scorecard method approaches the situation from a bigger perspective (Kaplan & Norton, 1992). Ghalayini and Noble (1996) considers the balanced scorecard method as an integrated performance measurement system framework on three levels: (1) strategic, (2) operational, (3) financial levels (Ghalayini & Noble, 1996). Figure 6 below illustrates an example balanced scorecard.

Financial Perspective

GOALS	MEASURES
Survive	Cash flow
Succeed	Quarterly sales growth and operating income by division
Prosper	Increased market share and ROE

Customer Perspective

GOALS	MEASURES
New products	Percent of sales from new products
	Percent of sales from proprietary products
Responsive supply	On-time delivery (defined by customer)
Preferred supplier	Share of key accounts' purchases
	Ranking by key accounts
Customer partnership	Number of cooperative engineering efforts

Internal Business Perspective

GOALS	MEASURES
Technology capability	Manufacturing geometry vs. competition
Manufacturing excellence	Cycle time Unit cost Yield
Design productivity	Silicon efficiency Engineering efficiency
New product introduction	Actual introduction schedule vs. plan

Innovation and Learning Perspective

GOALS	MEASURES
Technology leadership	Time to develop next generation
Manufacturing learning	Process time to maturity
Product focus	Percent of products that equal 80% sales
Time to market	New product introduction vs. competition

Figure 6. Example Balanced Scorecard (Kaplan & Norton, 1992).

As it can be seen in Figure 6, this example scorecard tells the managers which metrics to look for while analyzing the performance from different aspects. The power of this tool stems from improving the traditional financial methods with the addition of other aspects to it.

Secondly, SMART (Strategic measurement analysis and reporting technique) was developed due to the insufficiency of traditional measures. The aim was to provide a management control system that defines and controls firm's success. It is expressed as a four level pyramid with objectives and measures at each level. Figure 7 below, shows the architecture of SMART pyramid.

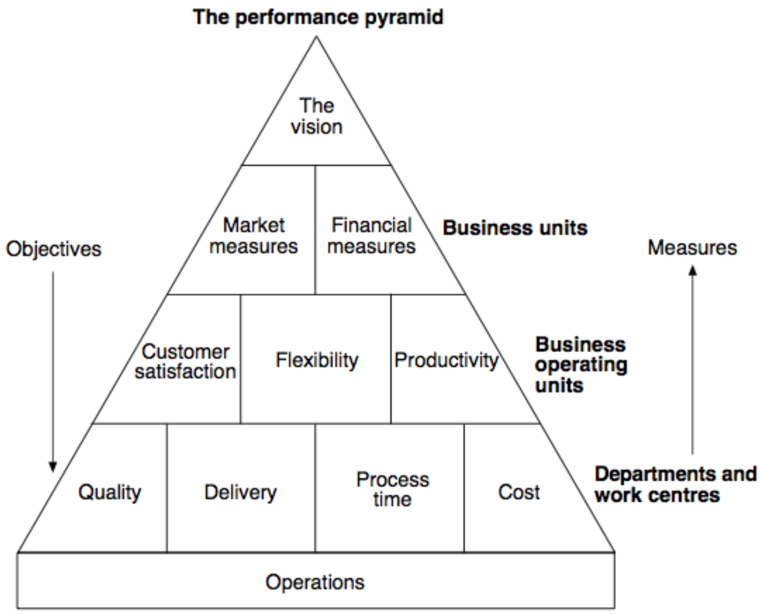


Figure 7. SMART pyramid (Ghalayini & Noble, 1996).

As it can be seen in Figure 7, at the top level there is corporate vision which assigns individual duties to business units and allocates resources to them. At second level, objectives are given to each operating units in terms of financial and market measures. More detailed and precise metrics can be defined to each business operating unit such as productivity or flexibility. At the fourth level, these metrics are defined by individual work objects. Therefore, operational measures which lie at the bottom of the pyramid are means to achieve individual goals which in turn contribute to firm's strategy and objective (Ghalayini & Noble, 1996).

Finally, performance measurement questionnaire (PMQ) is developed to aid managers to identify improvement needs of their firms. The main objective of this method is to ask systematic set of questions to higher level executives and understand that if an improvement area is important and if current performance measurement system supports these improvements (Ghalayini & Noble, 1996). Different than the two systems before, this one mainly focuses on improvement more than the others. As a comparison chart, Table 3 can be constructed to summarize the advantages and disadvantages of these methods.

Table 3. Comparison of Modern Performance Measurement Systems.

System	Advantage	Disadvantage
SMART	Aligning objectives and performance measurements	No mechanism to identify useful performance indicators
PMQ	Identifies improvement areas	Not often applicable
Balanced Scorecard	Simple	Targeted to higher levels

All in all, these systems are better without a doubt when compared to traditional methods. However, they also have their own weaknesses at different areas. Also what is missing in these systems is they fail to provide a strong forecasting mechanism. In order to make an ideal performance measurement system, companies often build and implement their own framework which is aligned with their needs. Nevertheless, it should be noted here that many firms continue their operations with wrong choices of metrics (Åhlström & Karlsson, 1996)

Powell (2004) states the detailed definition on the design and implementation processes of performance measurement systems. According to her interview with Professor Andy Neely, every performance measurement system consists of four stages that are:

- Design
- Implementation
- Managing decision making
- Refreshing

Firstly, design process can be thought as the stage of selection of metrics. Selecting the correct metrics that are useful can be challenging often. In addition, the frequency of measurements is another issue at this stage. As the frequency of measurements increase more time and resources have to be allocated for this purpose. Most of the firms are known to suffer from excessive measurement which results in overspent resources.

Secondly, implementation stage is the process of putting the selected measurements in practice. It may include the training and education of responsible people as well as building a computer system that will provide the data collection and analysis for the measurements. Understanding the purpose of the measurement, providing right people with right amount of data are the two issues that companies often struggle to sort out. When an employee is flooded with too much data, the purpose of performance measurement is partially lost for making correct decisions.

Thirdly, when performance measurements provide the required information there has to be a decision making process accompanied to it. Since each person can draw his own conclusion out of the same data set, decision making can be considered as a highly subjective matter. This may lead to conflicts inside the organization which eventually will make the performance measurement to lag as well. Instead of commenting on the data, focus must be on achieving the individual targets.

Finally, every performance measurement system have to be refreshed periodically due to the fact that changing nature of the business environment. Old reports have to be purged and the system of measuring the performance should be reviewed periodically to check that metrics are aligned and serving for the firms' objectives and strategies (Powell, 2004).

In this chapter, concept of measurement was defined first with two important attributes: (1) Reliability, (2) Validity. Expanding the idea to the business and management field, performance measurement was introduced. Although different types of classifications were possible, financial and non-financial performance measurements were selected as guidance to explain the concepts. It was claimed that with the change towards lean manufacturing a paradigm shift happened in performance measurement systems (Neely, 2005; Upton, 1998). Figure 8 below illustrates the topics covered in Chapter 3.

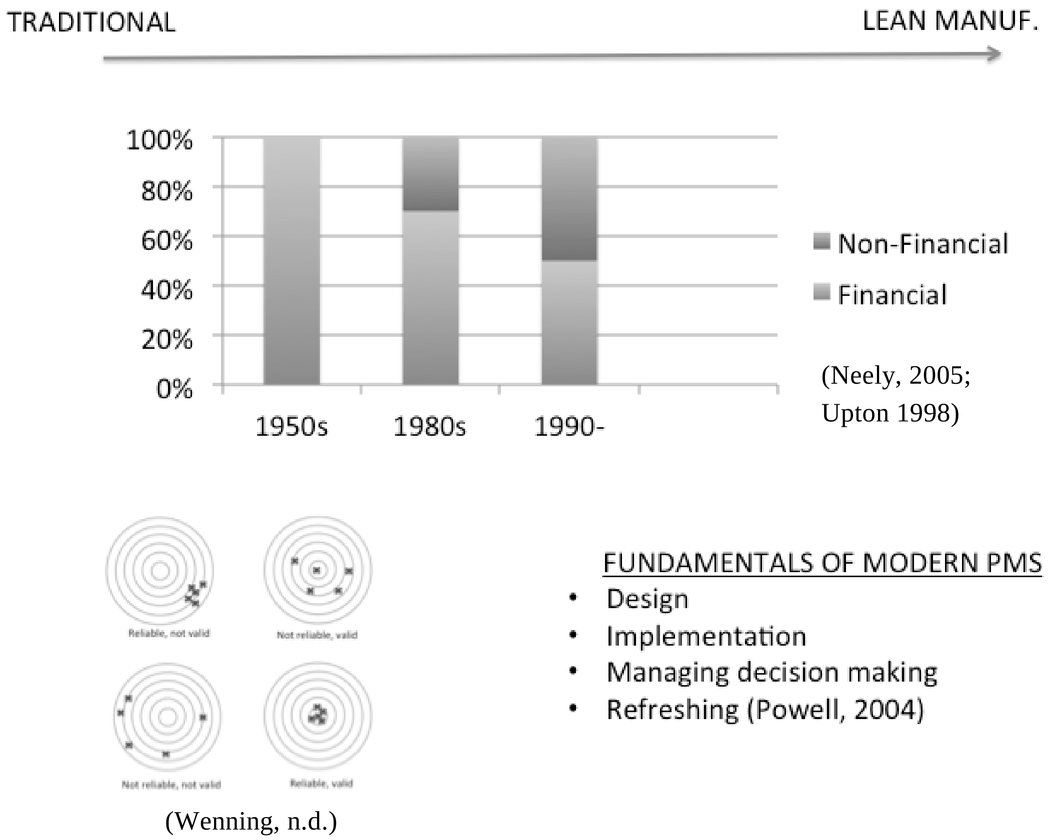


Figure 8. Conclusion of Chapter 3.

It was found out that only financial metrics were not sufficient enough for lean manufacturing philosophy. Hence, non-financial performance measurements had to be considered in order to have a more reliable and valid performance measures. As it can be seen from the figure above, more and more non-financial metrics were utilized by companies after the introduction of lean philosophy 1980s. Furthermore, the fundamentals of a modern performance measurement systems were explained in detail. Also, performance measurement systems were elaborated with their evolution throughout the history. The previous claim of using non-financial metrics more and more were also supported with the evolution process of performance measurement systems (PMS).

4 SUPPLIER CUSTOMER RELATIONS

In a normal market environment, customers are suppliers always interact with each other in order to maintain their businesses. Hence, they form relationships with each other. Depending on different factors, each customer and supplier forms different levels of relationship with each other. Also as indicated in two previous chapters, supplier-customer relations has also evolved throughout time, respectively. In this chapter, supplier-customer relationships will be elaborated and the concept of collaboration will be introduced. Later in the chapter, open book accounting which is a form of collaboration will be explained.

4.1 CATEGORIZATION OF SUPPLIER CUSTOMER RELATIONS

According to Webster (1992) as cited in Salle et. al. (2000), during 1980s big changes occurred in supplier customer relationship management. Relationships focus shifted from marketing mix to long term relationship and the emphasis moved on to partnership (Salle et al., 2000).

Although there are different classifications to supplier customer relationships in the literature, explaining two of them will be enough to give a main idea in two different perspectives. First, Groves and Valsamakis (1998) identifies three generic models of relationships which are:

- Adversarial
- Semi-adversarial
- Partnership model

Before explaining what each model means, it should be mentioned that Groves and Valsamakis (1998) used six factors to evaluate the degree of relationship between two parties. Meanings of these factors in three relationship models will be explained in order to give a clearer understanding of the categorization. These six relationship evaluation factors are:

- Basis of sourcing decisions
- Role of R&D in the relationship
- Management of quality
- Management of information flow
- Management of material flow
- Level of pressure in the relationship (Groves & Valsamakis, 1998).

First, basis of sourcing decisions implies that what motives are important for a customer when deciding from whom to source their items. In adversarial relationships, price is the biggest determinant and customer uses more than one supplier to create a price competitive environment. Regardless of frequency of transactions, there is no guarantee of maintaining the transactions for the future. In semi adversarial relationship number of supplier are considered to be less than adversarial and hence suppliers have to undergo an evaluation process in order to acquire that customer. More drivers other than price are involved in this type, such as quality or production capability. In partnerships, switching the supplier is not an expected case unless there is a persistent discomfort in the relationship. Therefore, benefits of both parties are the main sourcing decision driver in partnership type.

Second, in adversarial relationship both supplier and customer use their own resources for new product development. Customer states the product specifications to various suppliers and tries to select the cheapest one that meets the specifications. However as the relationship moves towards partnership, joint R&D activities can be seen. Hence, both supplier and customer are involved in the development of a new product. This saves resources for two parties and tends to yield more successful results.

Third, management of quality is considered only as a requirement in adversarial relationships, whereas in partnership quality of the supplied products concerns two parties at the same time. Customers can look for areas of improvement in their suppliers to ensure that they receive less faulty products in future. All quality improvements can be carried on with the involvement of both supplier and customer. In full partnership, customers always assess the quality of their suppliers and discuss the issues in case of a problem.

Fourth, level of information flow is also a deciding factor on the type of relationship. In the adversarial model, very little information is shared between supplier and customer since the trust is not present in the relationship. Therefore only transactional information is visible which is a necessity to maintain the sourcing activities. As the relationship shifts towards partnership side, more data is shared between two sides in order to achieve mutual benefit.

Fifth, management of material flow is highly limited in adversarial relationship model. Parties are not interested in the material flow management of each other as long as the transactions are maintained on time. In case of a late delivery, customer will probably switch to other supplier with a very low switching cost. Hence, both supplier and customer are independent to manage their material flows. Nevertheless in partnership model, both parties can be involved in the management of material flow of each other and joint investments can be made to improve logistics operations.

Sixth, level of pressure in the relationship is mostly on the price negotiations in adversarial relationship model. Other aspects such as quality or process development are not considered as a pressure aspect in these type of relationships. In partnership model, pressure shifts to continuous improvement in which two sides can achieve mutual benefits. Quality and performance measurement are also sources of pressure in partnerships as well (Groves & Valsamakis, 1998). After the explanation of relationship evaluation factors above, Table 4 can be constructed to summarize the three generic models of relationships.

Table 4. Relationship factors in three relationship types.

Factor / Relationship Type	**Adversarial**	**Semi-adversarial**	**Partnership**
Basis of sourcing decisions	Only based on price	Mostly based on price, partial quality consideration	Based on all aspects such as price, quality and effectiveness
Role of R&D	Independent R&D activities	Limited joint R&D activities	Joint R&D activities and investments
Management of quality	Separate	Small interaction in quality issues	Combined quality management activities
Management of information flow	Only transactional information is shared	A little more than transactional information is shared	Most of information is visible to achieve mutual benefit
Management of material flow	Individual management of material flow	Limited visibility of material flow	Transparent material flow
Level of pressure in the relationship	Price negotiations	Price and partially quality	Price, Quality, Development, Performance

As it can be seen in Table 4, each level of relationship has different characteristics. In addition to this generic classification, Webster (1992) identified seven types of relationships as cited in Salle et. al. (2000). These are:

1. Transactions
2. Repeated transactions
3. Long-term relationships
4. Buyer-seller partnerships
5. Strategic alliances

6. Network organizations
7. Vertical integration (Salle et al., 2000).

As it can be noticed from the list above, the level of relationship deepens from top to bottom. Combining the previous information from the model of Groves and Valmasakis (1998), Figure 9 can be constructed.

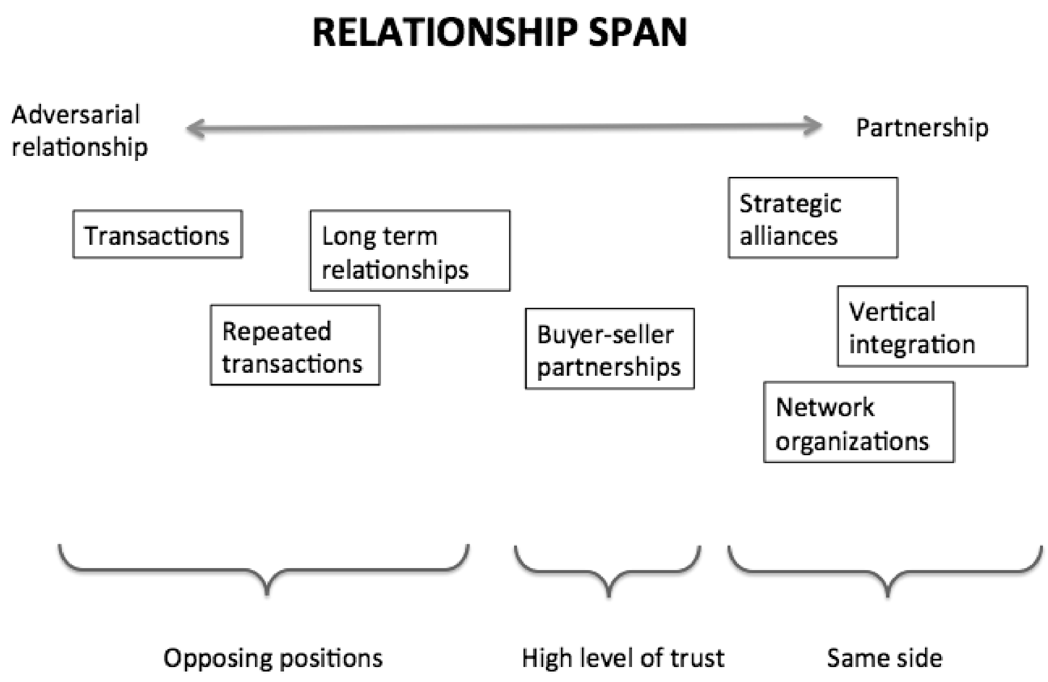


Figure 9. Relationship types (Salle et al., 2000; Groves & Valsamakis, 1998).

As it can be seen in Figure 9, there are various names for relationships for companies. However, sometimes it could be difficult to draw the line sharply and companies can be in a hybrid relationship type.

4.2 Collaboration in Supplier-Customer Relationships

The term collaboration has been popular among the companies in the same supply chains. Firms seek to gain advantage through collaborative buyer-supplier relationships. According to Vereecke & Muylle (2006), the concept of collaboration can be defined as a long term close relationship that will result in mutual benefit of the both sides by using open information exchange. Both sides try to benefit in terms of various aspects such as supplier performance, improved quality or solving disputes (Vereecke & Muylle, 2006). As in all types of relationships, collaboration can also be classified at different levels depending on the intensity of the collaborative actions. Again Vereecke & Muylle (2006) identifies two levels of collaboration which are:

- Operational
- Structural (Strategic)

First, operational collaboration refers to the idea of sharing information that will benefit both the supplier and the customer and this is defined as the basic form of collaboration. According to Vollmann et. al. (2005) cited in Vereecke & Muylle (2006), shared information can be at different levels such as planning and controlling the production, demand forecasting and so on. Lee et. al. (1997) emphasizes the importance of information sharing and claims that it is a powerful mechanism to improve performance, reduce production lead time and reveal cost reduction areas effectively (Lee et al., 1997). Second, structural or strategic collaboration can be explained as a more structured way of collaboration and information sharing. It may involve joint planning of products and processes so that both parties are likely to benefit from this “proactive” approach (Vereecke & Muylle, 2006). Depending on the trust and relationship level it can be guessed that operational collaboration is the first step which may continue with structural collaboration over the time as both sides build mutual trust with each other.

Few logical deductions can be made combining the information from the literature. It is known that the collaboration level increases with the increased sense of trust between parties and more information is expected to be shared with this increased trust. Based on this, following figure can be constructed.

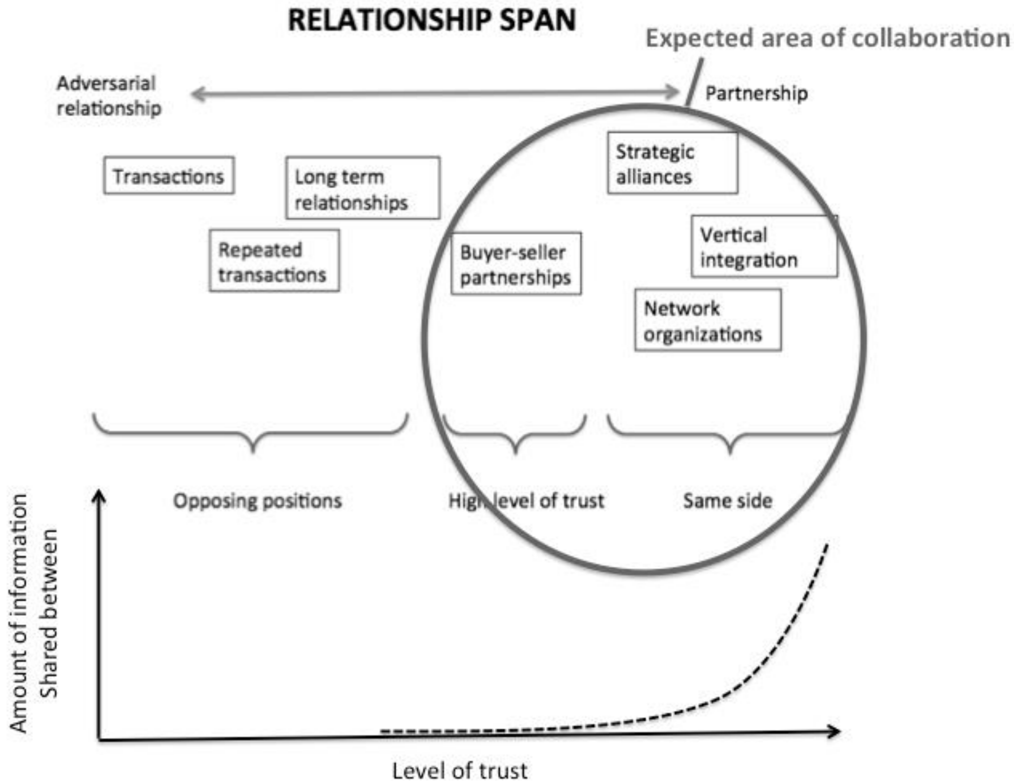


Figure 10. Collaboration in supplier-customer relationships. (Salle et al., 2000; Groves & Valsamakis, 1998; Vereecke & Muylle, 2006)

As it can be seen in Figure 10 above, concept of collaboration depends on the level of trust naturally, since it is an activity of information sharing. Hence, it can be expected that collaboration may begin and develop as the parties move from adversarial relationship towards partnership.

4.3 Collaboration via Open Book Accounting

It was explained in the previous chapters that collaboration relies heavily on information sharing. In this chapter open book accounting which is the most common type of information sharing will be explained in detail. Open-book accounting (OBA) is the rising trend of modern management which can be explained as the sharing of financial data between two or more parties. Generally, these parties are within the same supply chain or supply network. Companies share their financial data with their supplier side or customer side partners to gain competitive advantage in the markets. According to Suomala et. al. (2010), although open book accounting is getting more popular in the literature, real-life application of the methods and justifications are still relatively weak. Open book accounting is one of the sub-components of inter-organizational cost management (IOCM) and consists of sharing various cost information in a supplier-customer relationship (Suomala et al., 2010). Mouritsen et. al. (2001), defines OBA as a strategy that leads firms towards collaboration which uses information sharing as a tool to improve flow of products or services. In addition, cost saving projects can be initiated by both sides that results in a mutual benefit for the both firms (Mouritsen et al., 2001). Based on this information the following figure can be constructed to illustrate the area for OBA in supplier-customer relationships.

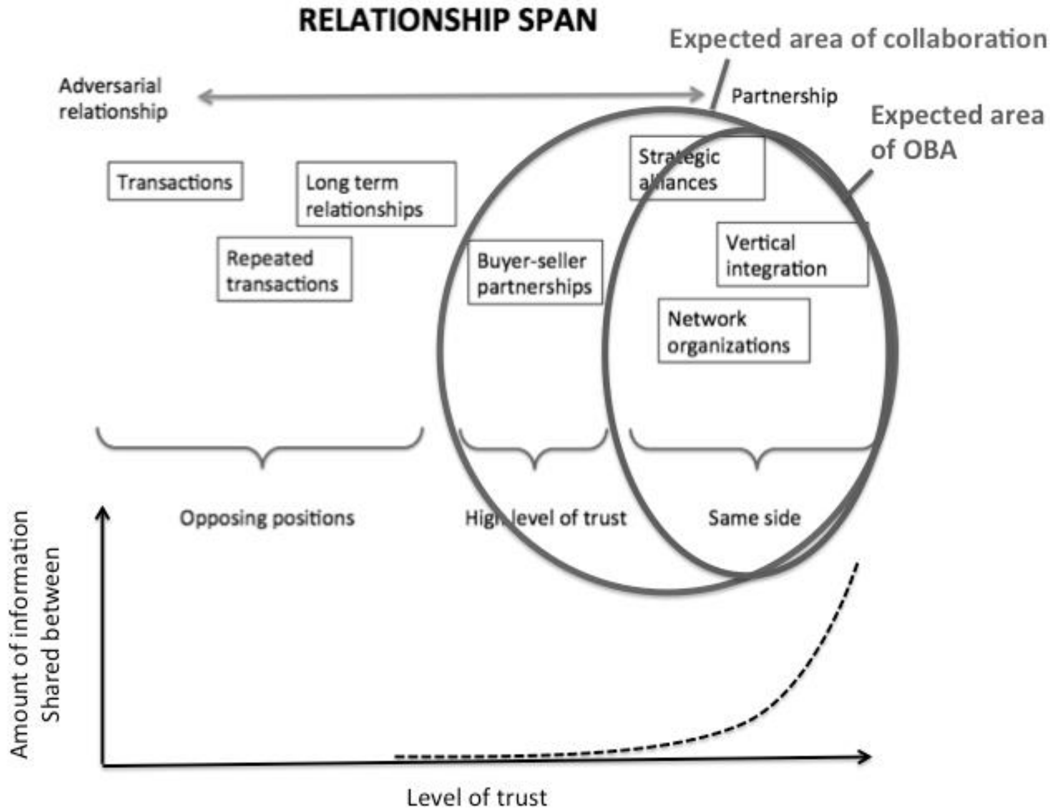


Figure 11. OBA, collaboration and supplier-customer relationship levels.

In Figure 11 above the possible application area of OBA is illustrated with comparison to supplier-customer relationship level. Since OBA consists of sharing sensitive cost information, it cannot be expected for the firms to share this information at adversarial relationship level. Hence, a certain level of trust is required to build OBA practice. Therefore, OBA and collaboration are certainly linked with the partnership side of customer-supplier relationships. According to surveys cited in Kajüter et al. (2005), OBA has been observed to be in practice in Japanese companies more than European firms. Since lean manufacturing is known to be more common in Japan, this may imply that lean manufacturing principles has strong influence to initiate and adopt to OBA. However the evidence is lacking to prove this claim strongly (Kajüter & Kulmala, 2005).

OBA requires and results in increased collaboration during the implementation and there are various reasons why firms choose OBA. Suomala et. al. (2010), defines these motives as the following:

- Short-term cost reductions
- Supplier's selling price revisions
- Improved operating policies between supplier and customer
- Agreements on cost targets
- Showing mutual commitment (Suomala et al., 2010)

Among these motives, cost reduction is often the main point since all the other aspects will lead to cost reduction eventually. Therefore, it can be said that information shared in OBA is most of the time either financial or financially related data, since they are the means to cost reductions. In addition to this, it was explained that OBA is a sub-component of IOCM. Hence OBA has the nature of cost management. Kajüter et al. (2005) claims that IOCM has remote relation with the context of network influences during the adoption process (Kajüter & Kulmala, 2005). This means that IOCM has a tendency to spread across the supply chain network once two parties start to use it effectively. However, there is very little evidence for OBA adoption process and previous literature only focuses on contextual variables (Kajüter & Kulmala, 2005).

IOCM and OBA are two mechanisms that enable companies within the same supply network to benefit from cost reduction possibilities by sharing each others' financial data and cost information. As it was mentioned above there are various motives or aims to apply OBA. Therefore, it would not be wrong to say that non-financial data can also be shared and used in the context of OBA. Although there is a bias towards thinking that OBA only consists of sharing of cost information, it does not have to be so. Even though it may seem that non-financial data sharing is not related with the cost management or accounting, it may still reveal areas of improvement in terms of cost reduction which is the ultimate goal of IOCM and OBA. Hence any information that may lead to reveal cost reduction can be shared among the companies within the practice of OBA.

To conclude, OBA accounting is still one of the novel areas in management practices and extant literature gives very little information about its applicability and benefits. One of the reasons for this difficulty is that it is highly context dependent and existing mechanisms can not be applied generically to every case. However, failure in OBA often means to give up on using OBA which implies no drastic consequences on the trial of adoption of OBA (Suomala et al., 2010).

In this chapter, supplier-customer relationships were explained in detail. Although there are different methods to categorize supplier-customer relationships, one model was adopted by using the information from Groves & Valsamakis (1998) and Salle et. al. (2000) to be used as guidance throughout the chapter (Groves & Valsamakis, 1998; Salle et al., 2000). There found out to be 7 levels of relationship depending on various factors between suppliers and customers. Collaboration, one of the concepts also seen in lean philosophy refers to the activities of information sharing and trying to identify areas that both parties can benefit from. In lean philosophy collaboration can be one of the areas that provides competitive advantage to both sides. Figure 12 below illustrates the concepts covered in Chapter 4.

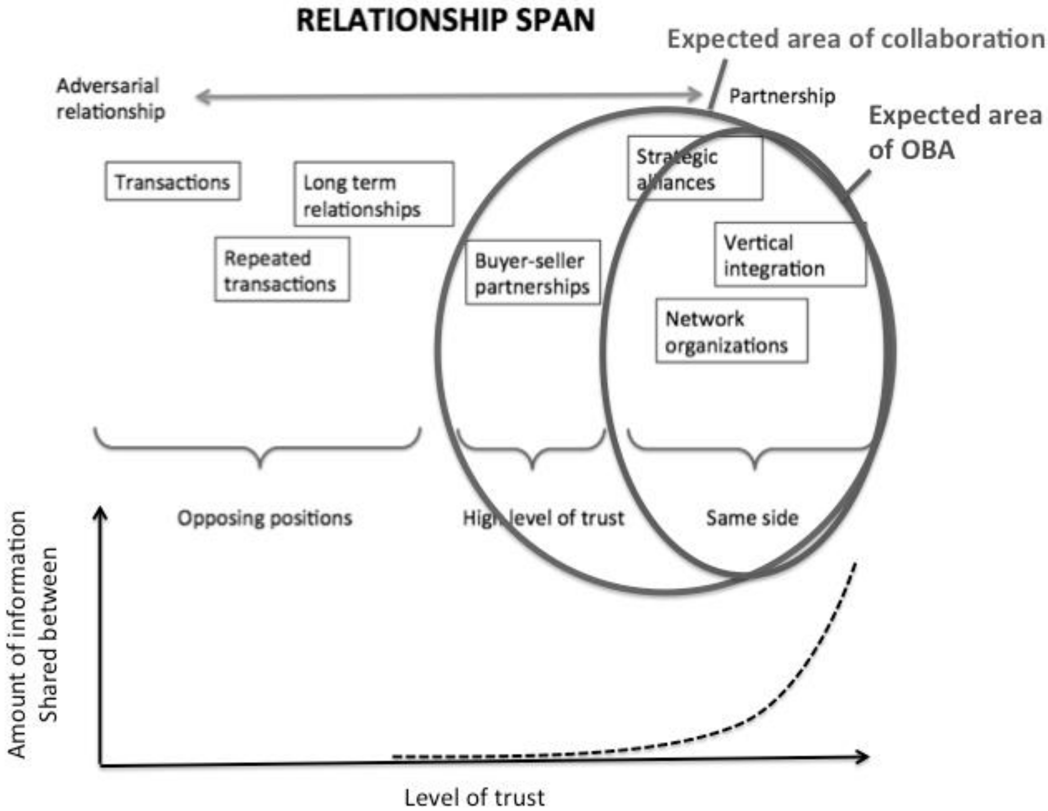


Figure 12. Summary of Chapter 4 (Suomala et al., 2010; Salle et al., 2000; Groves & Valsamakis, 1998).

As it can be seen in Figure 12, collaboration or information sharing is expected to begin as the level of trust in the relationship increases. Open-book accounting (OBA) which can be seen as a special form of collaboration, involves sharing of financial information between supplier and customer in order to seek and find possible cost reduction areas. With these cost reductions both parties are expected to have more competitive advantage in their respective markets. Although OBA seems to require a higher level of trust, it is still one of the novel areas that has to be researched more (Suomala et al., 2010).

5 CONSTRUCTING THE FRAMEWORK

In this chapter, the framework will be constructed based on the three chapters explained above. In the previous chapters, separate literature reviews were conducted to familiarize the reader with the concepts. The framework will be constructed considering the connections between three aspects as it is illustrated in Figure 13 below.

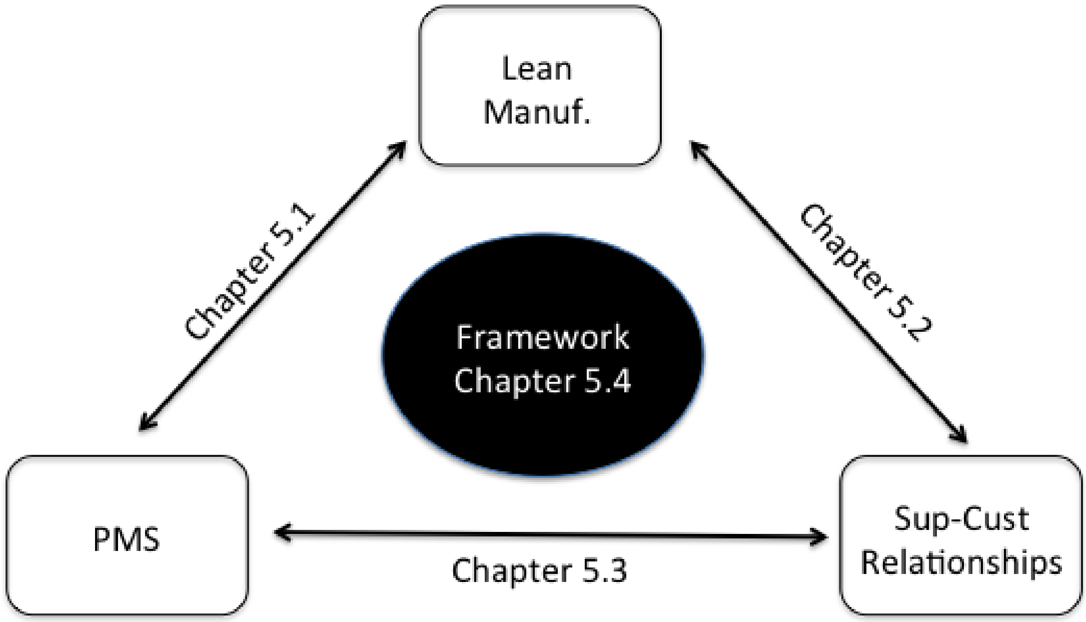


Figure 13. Roadmap to the framework.

As it can be seen in Figure 13, there will be 3 dimensions in the framework. Each of these dimensions are already explained individually in the previous chapters. In this chapter, their connections with each other will be analyzed before introducing the framework. Finally, the framework will be introduced combining all three dimensions and will be analyzed in detail.

5.1 LEAN AND PERFORMANCE MEASUREMENT SYSTEMS

Regardless of the classification method or design process, various authors defined how an ideal modern performance measurement system should be. It is beneficial to define and review how ideal performance measurement systems should be and to what points firms must pay attention while building their own performance measurement system. While doing that, current manufacturing trends are considered such as lean manufacturing, JIT production or Total Quality Management (TQM). After 1990, JIT systems influenced performance measurement systems and accounting metrics as well as changing the expectations of the firms from performance measurement systems (Upton, 1998).

In order to define the characteristics of ideal performance measurement systems, requirements of modern manufacturing methods (specifically lean manufacturing) have to be reminded once more. Lean manufacturing focuses on customer satisfaction, continuous quality improvement, shorter lead times, increased flexibility, pull production and producing with lower inventory (van Schalkwyk, 1998; Ghalayini & Noble, 1996). Therefore, performance measurement metrics must be aligned with this objectives of lean manufacturing as well as being dynamic and easy to use.

Five authors made extensive definitions and requirements of performance measurement systems for lean manufacturing. Some of the items are claimed by more than one author, but in general an ideal PMS must include the following points:

- Alignment with the corporate strategy (Parker, 2000; van Schalkwyk, 1998; Najmi et al., 2005)
- Coordination between lower and higher levels (Parker, 2000)
- Commitment to the performance measurements (Parker, 2000; van Schalkwyk, 1998)
- Measurements must influence performance (Parker, 2000)
- Reliability (Parker, 2000; van Schalkwyk, 1998)
- Visibility inside the organization (Parker, 2000; van Schalkwyk, 1998)
- Relevant (van Schalkwyk, 1998)
- Frequent reporting (van Schalkwyk, 1998)
- Simple and easy to use (van Schalkwyk, 1998; Ghalayini & Noble, 1996; Najmi et al., 2005; Åhlström & Karlsson, 1996)
- Focuses on customer satisfaction (van Schalkwyk, 1998)
- Not used as a weapon against employees (van Schalkwyk, 1998)
- Dynamically reviewed (Bititci et al., 2000; Ghalayini & Noble, 1996; Najmi et al., 2005)
- Sensitive to changes in environment (Bititci et al., 2000)
- Make improvement areas visible (Ghalayini & Noble, 1996)

Based on these points, some conclusions related to the characteristics of an ideal performance measurement system can be drawn. First, performance measurements must not be only measurements. In fact, the whole point of performance measurement is to take action against changing environment. Another common view on modern performance measurement is that ease of use. Most of the time managers struggle while mining the data and making comments out of it. Performance measurement systems must provide the simplest results and it is even better if they are able to make suggestions for some specific situations. Third, dynamic reviewing of performance measurement systems is one of the most important aspects of the idea. Since both internal and external environment of organizations are changing throughout the time, these measurement systems have to be reviewed and necessary changes must be applied periodically.

Focus of the performance measure is the most critical part of it. It is evident that firms are nowadays looking more than low cost products only. It was mentioned before that some of their requirements are quality, reliable delivery, flexibility and shorter lead time. Although there is a vast amount of research done to define and measure flexibility, it is still not possible to get a measurement of flexibility that is suitable for practical use (Primrose & Verter, 1996).

In reality, organizations are unlikely to take action based only on one measurement. The decision making process requires evaluation of many metrics as possible. Therefore, even though one metric is lagging the other ones will prevent the firm from making the wrong decisions. However, after all these points, supposedly there is a non-certain optimal point for every company. Figure 14 shows this correlation between the number of metrics used versus effectiveness of the current performance measurement system.

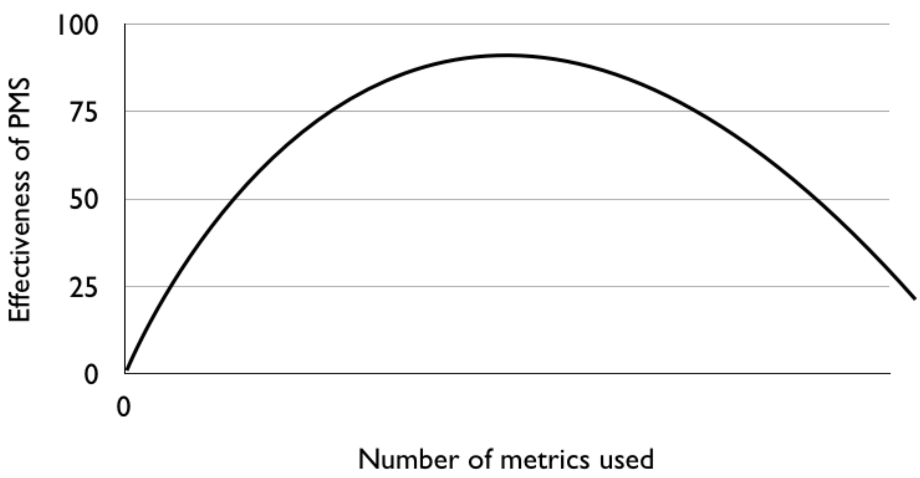


Figure 14. Effectiveness of PMS versus number of metrics used.

As it can be observed from Figure 14, if no metric is used there will not be any effectiveness of PMS. As the number of metrics increase first issue will be the danger of lagging metrics. Hence the effectiveness will not rise sharply because of this. Few metrics can be quite useless if they all provide delayed data. Therefore, there is either a need for more metrics or different metrics. A small company can manage its operations quite effectively with only a few metrics if they are chosen correctly.

While the number of measurements used increase, it reaches the hypothetical optimal point and after this the effectiveness begins to decrease. The reasons for that are mostly the complexity of PMS and spending a tremendous amount of resources to mine and analyze the data. This will lead to an unnecessary waste, which is not correspondent with the lean philosophy as well as extending the decision making time. Another aspect that has to be reminded is that the effectiveness of PMS is not a stable value for long time, meaning that it may increase or decrease with the changes in the business environment. This certainly forces organizations to review and re-evaluate their performance measurement and make corrections to align it with their strategy and objectives.

While making a correlation between lean and performance measurement systems, it can be stated that excessive performance measuring is also a waste of resources and not suitable for lean manufacturing philosophy. Therefore, a vast amount of metrics are also some type of waste (muda) that have to be eliminated. Considering the previous wastes defined above by Hajek (2009), the list now becomes the following:

- Transport
- Inventory
- Motion
- Waiting
- Over-processing
- Overproduction
- Defects (Hajek, 2009)
- **Excessive metrics.**

Excessive metrics are definitely a waste of resource in both ways. First, it requires a considerable amount of investment in IT systems in order to be able to obtain the data. In larger companies this is likely to be more difficult and time consuming to set up. Secondly, it is also a waste of resource in terms of the decision makers since they have to dig through the data and make logical comments out of it. Decision making process will be much slower when there are too many metrics to analyze and evaluate. Therefore, excessive performance evaluation metrics has to be considered as a waste and optimized properly.

5.2 LEAN AND SUPPLIER CUSTOMER RELATIONS

The change towards lean manufacturing started show its effects in 1980s in Japan and spread to other countries in early 1990s. Adopting to lean philosophy by reducing the waste requires a bigger approach than only focusing to direct manufacturing processes. Supply chain management (SCM) was widely adopted by developed countries in the beginning of 1990s (Agus & Hajinoor, 2012). Helper (2001), as cited in Wu (2003), found in her survey that it is crucially necessary to establish long term mutual relationships between suppliers and customers while adopting to lean philosophy (Wu, 2003).

With the increasing demands from customer side, suppliers have to learn how to adopt to their customers' ever changing needs. In addition, companies constantly have been trying to make their supply chains more competitive holistically. Therefore, a company trying to implement lean philosophy is likely to initiate its suppliers in order to follow JIT philosophy effectively (So & Sun, 2010). This created a trend of collaborative relationships between customers and its suppliers. When the lean philosophy was more and more widely accepted, a lot of buyer supplier relationships were developed in order to survive in the competitive environment. It is also known that lean philosophy brought a reduction in the overall number of suppliers (Wu, 2003). Instead of having many suppliers, companies are trying to have few suppliers which they can rely on. Figure 15 below shows the position of lean manufacturing philosophy in terms of supplier-customer relationships.

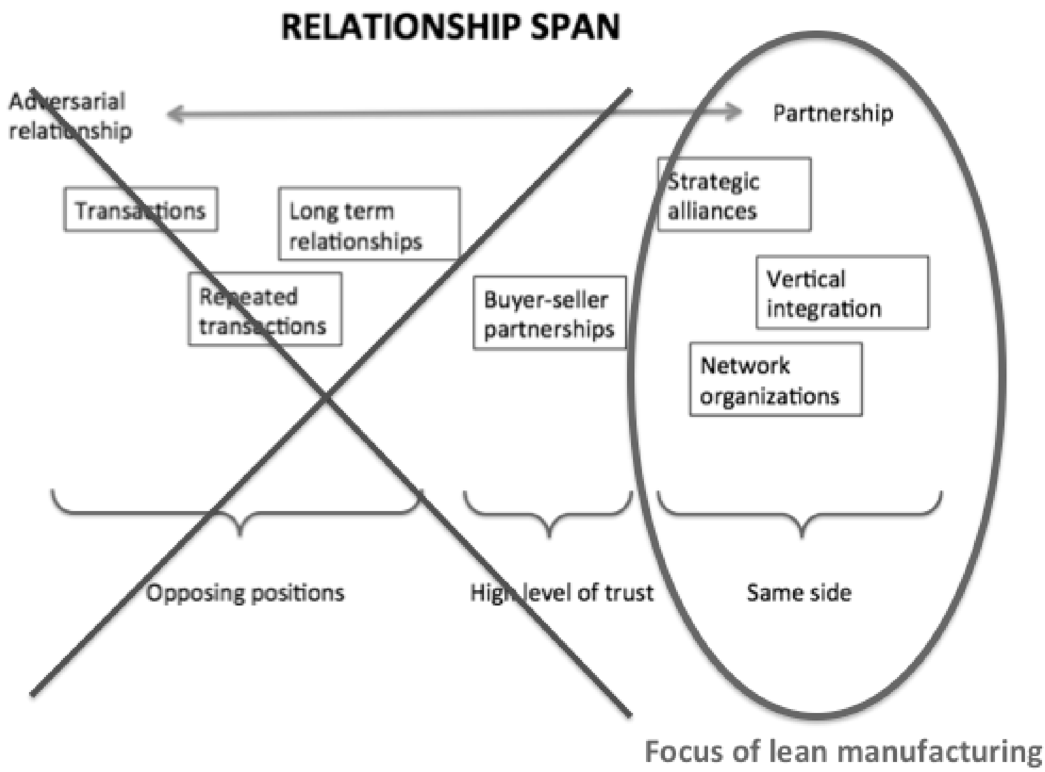


Figure 15. Lean manufacturing and supplier-customer relationships.

In Figure 15, it can be observed that lean manufacturing focuses on the partnership side of supplier-customer relationships. This is due to the nature of collaboration in lean enterprises. It was explained in Chapter 4.2 that some level of trust is required to have collaboration and information sharing activities. Therefore, collaboration in supply chain, being a vital element in lean manufacturing philosophy, requires firms to move closer to partnership side to enable its potential benefits.

Another important point to mention here is the correlation between OBA and lean manufacturing philosophy. It was noted earlier that OBA and IOCM requires collaboration and high level of trust between parties. Level of trust increases as companies move from adversarial relationship to partnership side. Hence the information shared between supplier and customer increases with this shift. Collaboration begins with the information sharing and builds up deeply as more and more information is shared. OBA and IOCM on the other hand, requires a commitment to collaboration. Therefore it was concluded that OBA may happen as the collaboration increases between parties. Based on deduction of the previous information provided, the following figure can be constructed.

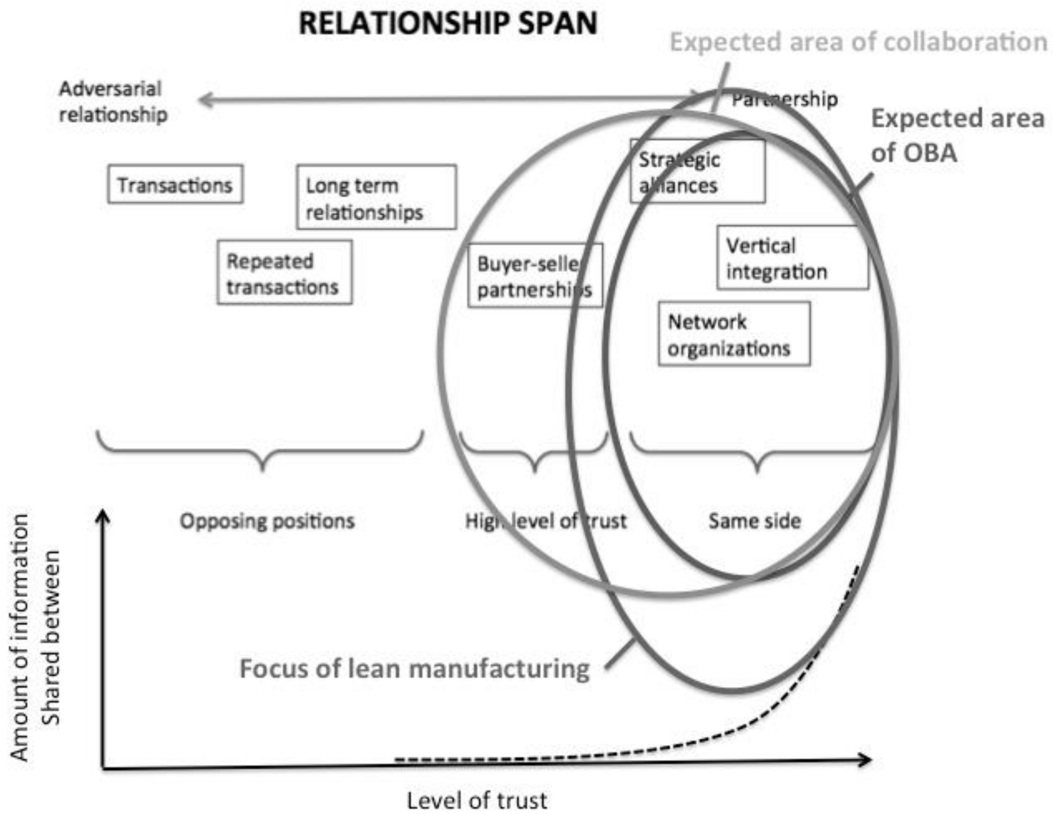


Figure 16. OBA and lean manufacturing in context of supplier-customer relationships.

Figure 16 shows the correlation between OBA and lean manufacturing. Extant literature also supports this deduction, however strong proof is lacking since OBA is a relatively new concept in management practices. According to surveys cited in Kajüter et al. (2005), Japanese firms are found to be practicing OBA more than European companies. This may clearly be an implication of correlation between OBA and lean manufacturing, since the lean supply concept originates from Japan and sharing of cost data may be more common in Japanese firms due to this reason (Kajüter & Kulmala, 2005). However, it can be concluded that both lean and OBA meet at the common grounds of collaboration.

5.3 PMS AND SUPPLIER-CUSTOMER RELATIONSHIPS

Depending on the position on the relationship span, there are different expectations between supplier and customer relationships. In adversarial relationships, supplier and customer do not share any metrics at all since the mutual trust is not present. As the partners move closer to each other more and more information and performance measurements become visible to both sides. Figure 17 below shows the change in visibility versus the relationship type.

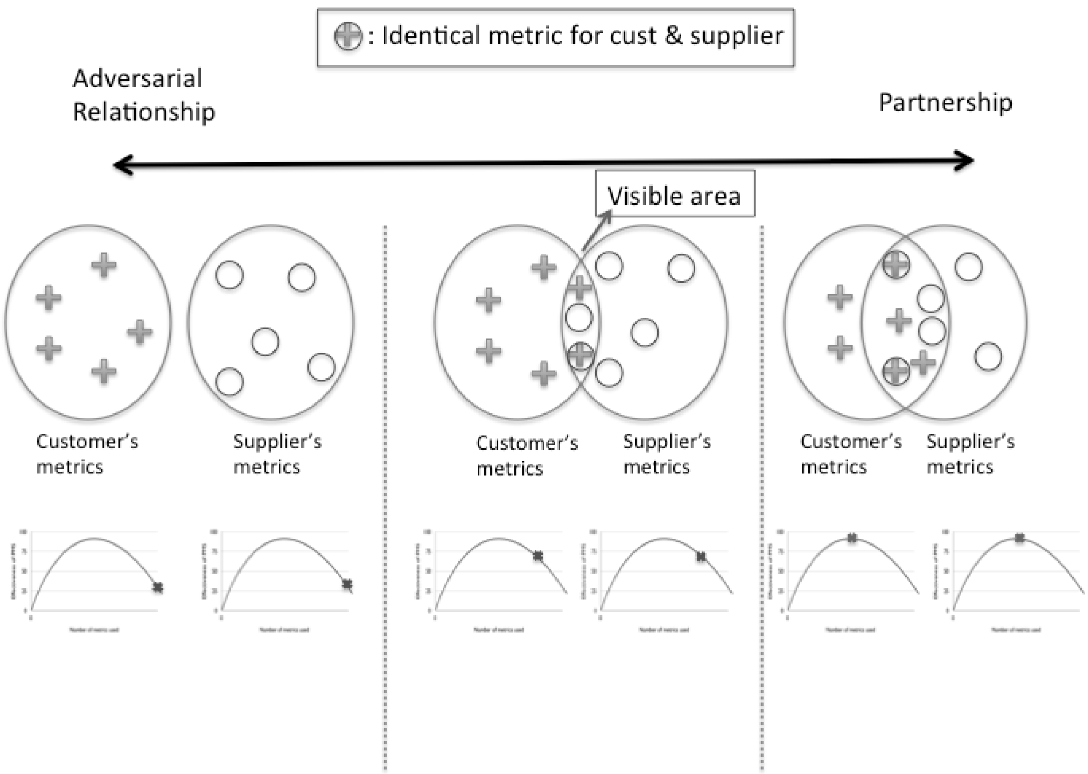


Figure 17. Changes in the visibility of metrics versus the level of relationship.

As it can be seen in Figure 17, the metrics become more and more visible between two parties as the relationship moves from adversarial (transactional) to partnership. In adversarial relationship, both supplier and customer may be using the same metrics however, they are not visible to the other side. Figure 18 below shows the change in visible common metrics versus the level of relationship.

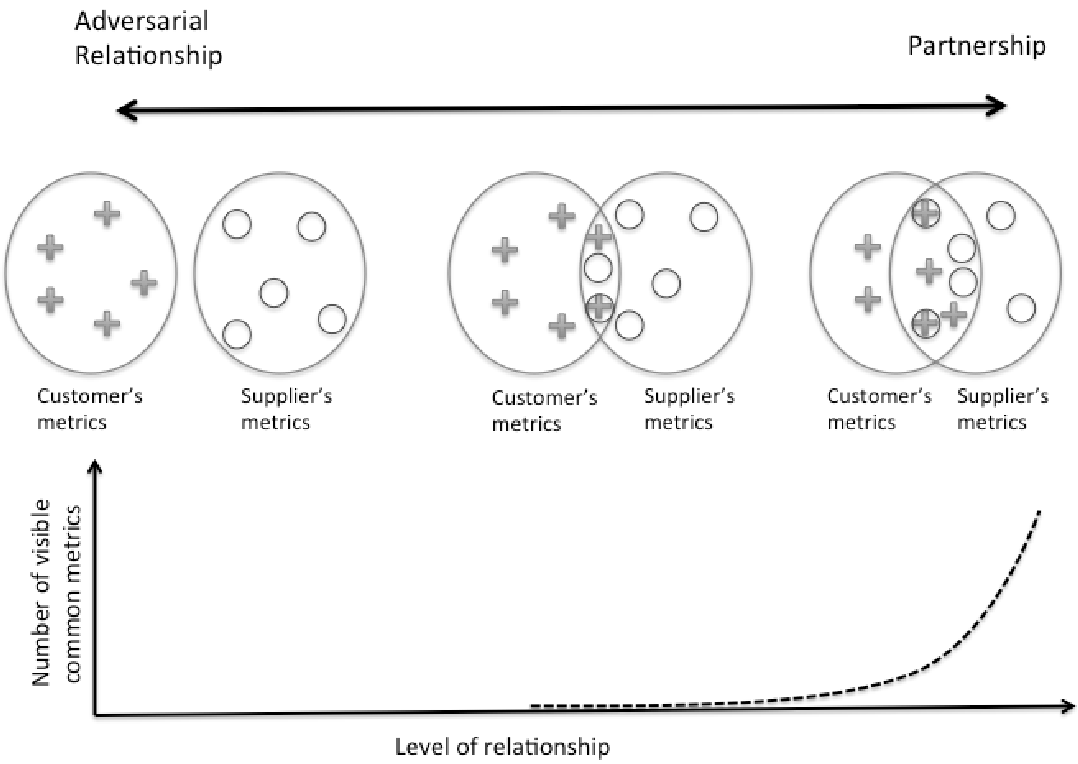


Figure 18. Number of visible common metrics versus level of relationship.

As the relationship intensifies, the metrics of both parties become visible to each other. It has been quite common that customer checks the inventory levels or production schedule of its supplier while making a purchase order. Reverse scenario is also possible which can be explained as distributors check and manage the inventory levels of their retailers (Vendor Managed Inventory). Some of the metrics that are beneficial for both parties can be listed as the following:

- Inventory levels
- Production scheduling
- Financial metrics (ROI, Profitability…etc)
- Shipping scheduling
- Delivery performance
- New product development cycle time
- Production lead time

The above list are only a portion of shared metrics, whereas in reality there could be even more than these. In addition to these, rarely customer and supplier measure the same performance metric but separately from each other. As the level of relationship deepens, these also become visible to both sides. Hence, there happens to be a possibility to check and compare same metrics, but coming from two different sides. However, parties tend to ignore the duplicate metrics, if it is already available from their side. This can be explained as a result of mutual trust between supplier and customer. Nevertheless, there is always a possibility that these two identical metrics show a mismatch. Naturally the possibility of a mismatch is more, as the number of identical metrics are present. Since the number of identical metrics are noticed as the level of relationship changes, following figure can be constructed.

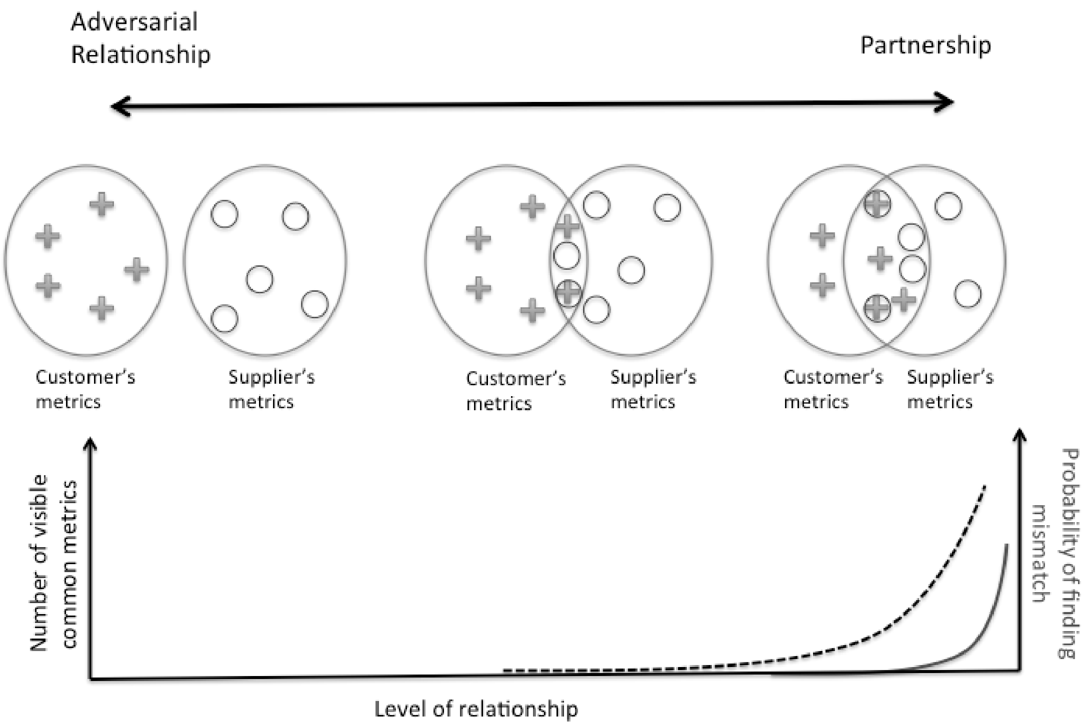


Figure 19. Relationship type versus mismatching metrics.

Figure 19 shows that as the level of relationship moves towards to partnership side, the probability of finding a mismatching metric increases. This is due to the fact that more and more metrics become visible to both parties. This mismatch is often not easy to notice, because each side may choose to use their own metric when it is also available from the other side. Since these same metrics are not compared at all, there is no way to identify this mismatch until there is a problem associated with that specific metric.

Literature review gives a small information about what these identical metrics could be between suppliers and customers. According to Groves and Valsamakis (1998), mismatch is known in lead times especially when the exporting activities are frequent and parties are geographically distant from each other. Furthermore, non-overlapping metrics were found in development cycle time and number of new product launches per year (Groves & Valsamakis, 1998).

5.4 PMS IN LEAN PARTNERSHIPS – FRAMEWORK

It has been explained that lean manufacturing required a change in management philosophies. Most of the traditional metrics which were more than enough previously, failed to be successful in lean environment. Another aspect of lean philosophy was the change in customer supplier relationships. Firms had to develop close relationships with their suppliers in order to gain competitive advantage and survival in the market. This caused them to decrease their number of suppliers and move towards to partnership from transactional relationships.

The common point of these two changes is that firms were now focusing on quality reliable deliveries, customer satisfaction and flexibility rather than only cost. This made the financial metrics to fail and shifted the customer supplier relationships closer to partnership side.

There are three parameters which are inter-connected with each other: (1) Lean manufacturing, (2) supplier customer relationships and (3) performance measurement systems (PMS). Since no solid results were found during literature reviewing, the connection between PMS and supplier-customer relationships will be introduced in this chapter among with the framework.

When firms develop closer relationships with their suppliers, the level of information flow between two parties increases and information becomes visible to both sides (Groves & Valsamakis, 1998). This is a necessity for them since both parties are trying achieve mutual benefit from the relationship. The main reason behind this visibility is that both sides seek for improvement areas and it is often the case that both sides of supply chain has to be analyzed and improved for achieving great cost benefits. Depending on the number of partners this situation may extend to whole supply chain. Before constructing the framework, it is beneficial to remind the all the three aspects of it. Evidently framework combines the following three aspects:

- Supplier-customer relationships
- Performance measurement systems
- Principles of lean manufacturing

With the information provided before, bottom line of the all three aspects can be drawn with the following framework as illustrated in the figure below.

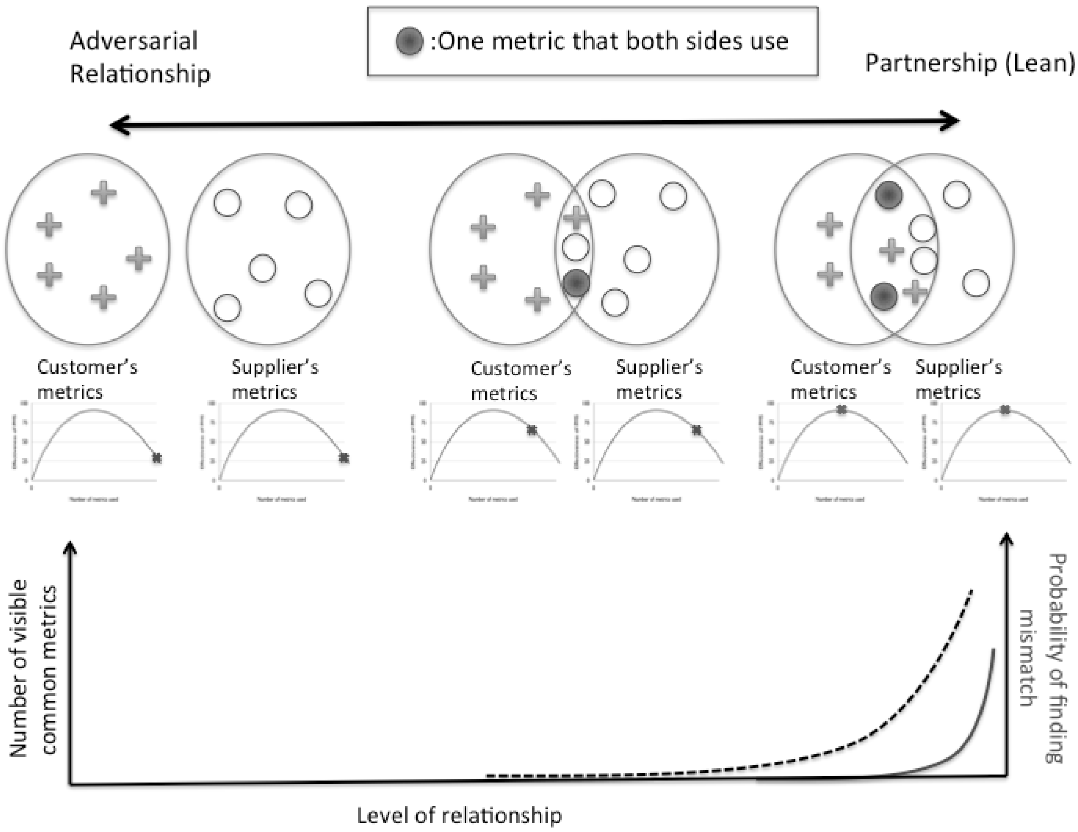


Figure 20. The first part of the framework.

As it is seen in Figure 20 above, there is a continuous line that defines the level of supplier customer relationships. On the left hand side, there is adversarial relationship where the relationship is mostly based on transactions. Adversarial relationships do not support information sharing, since the level of trust is remarkably low between two sides. Information such as metrics are considered to be sensitive and confidential, hence each side uses their own metrics to measure both their own and the opposing side's performance. Metrics or performance measures of both sides are not visible to each other. At this point, there is always a possibility that both sides may be measuring the same thing but it is not known by or accessible to the other side. This is likely to create waste (muda) in terms of performance measuring, due to the fact that performance measuring is a resource consuming activity in the end.

As the relationship level moves towards to the middle of the line, some sense of trust is likely to develop between suppliers and their customers. This trust triggers the sharing of information in between, for the purpose of mutual benefit which can be considered as the beginning of collaboration. One side can analyze the other side's metrics and try to develop a strategic move that can end up in a win-win situation. This sharing of information creates a possibility to find common metrics between two sides. Nevertheless, the level of trust is not considered to be high enough. Therefore, these shared metrics are often vulnerable to be ignored, because of the preference of each side to use their own metric most of the time.

Finally, the level of trust becomes considerably high, when the relationship level moves to the partnership side. The aim of the partnership is to search and create opportunities that can benefit both parties and both sides strive for these opportunities most of the time. While the number of visible metrics to both sides increase, the possibility of finding a mismatch in the metrics increases. This mismatch is supposed to be found on the exactly same metrics. Although other derived metrics such as combination result of two or more performance measures do not seem to be impossible. The literature seems to be providing very little information on what these common metrics might be. However, metrics such as on-time-delivery performance or other financial metrics initially are highly expected to be compared by both sides as a nature of business environment. Figure 21 below illustrates the full framework.

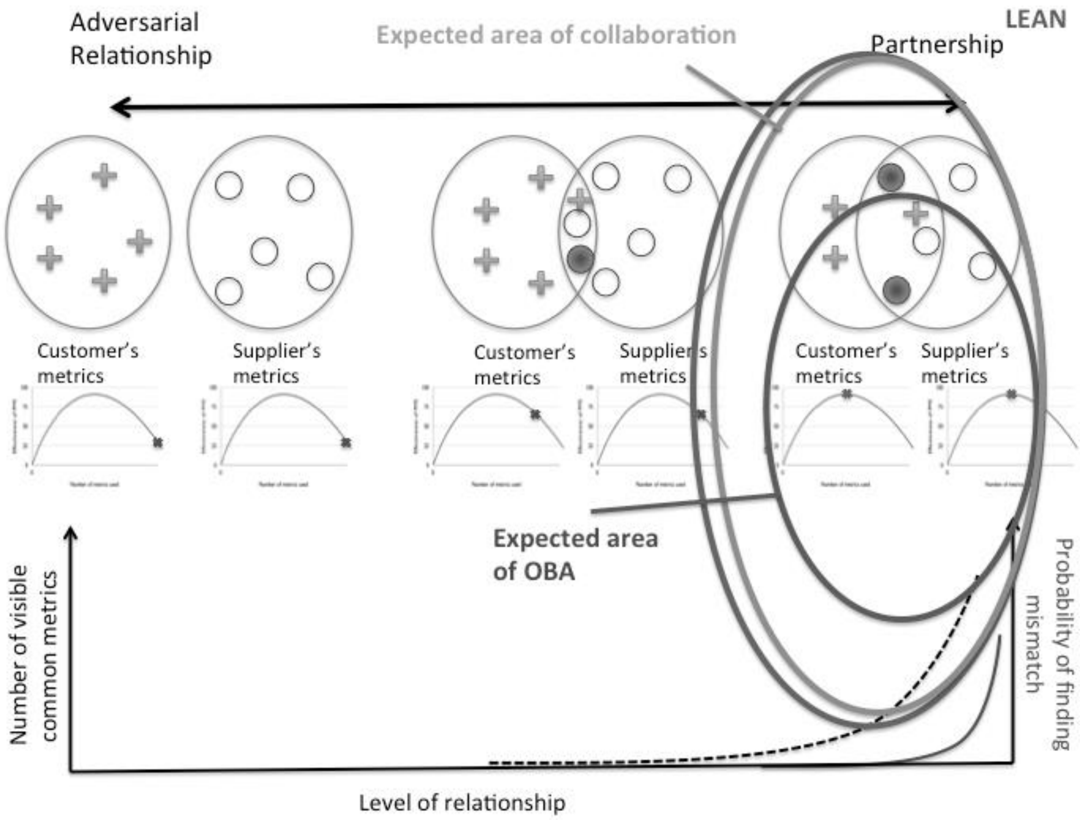


Figure 21. Full framework.

Possibility of finding a mismatch is actually quite beneficial for the partners since it should lead to the process of troubleshooting in a partnership environment. Instead of partners trying to justify their own metrics first the reasons of the mismatch will be analyzed. Eventually, both sides will resolve the conflict and start using the metric that is reliable and valid for them. This should lead to a reduction in the overall number of performance measured and benefiting both sides in two aspects:

- Increased efficiency of performance measurement systems
- Waste reduction in terms of excessive metrics

First, excessive number of metrics are often a burden for the firms since they have to spend tremendous amount of resources to built the system to measure. Also, making decisions based on too many measures is also more time consuming for the decision makers, again making the efficiency of the PMS lower, referring to Figure 14 given in Chapter 5.1. With the agreed metric which both sides will be using after troubleshooting, the efficiency of the PMS are expected to increase. Second, approaching from lean manufacturing aspect, excessive metrics are considered to be wastes of resources for the reasons explained above, hence they have to be optimized.

In addition to all these, sharing of metrics can be viewed as a practice of OBA. It was noted before that in OBA also non-financial data can be shared as long as it serves for the purpose of cost reduction. Performance metrics in this sense can also be considered as a non-financial data. However these metrics will probably help in terms of cost management and cost reduction. Therefore, sharing performance metrics can be also considered as an aspect of OBA which is likely to occur lean partnerships that require extensive collaboration, supporting the previous claims. However the initiation of OBA may follow at the later stages of partnership as it needs both parties to trust each other at a certain level.

To summarize the framework, lean manufacturing philosophy requires suppliers and customers to move towards partnership side and involves them in collaborative activities. This movement triggers the sharing of both financial and non-financial information among parties. Performance metrics which can be both financial and non-financial information are part of this information sharing. From another perspective this shared performance metrics can also be viewed as a practice and a part of open-book accounting. As more and more information is shared, the probability of finding a mismatch in the performance metrics increases. Since both sides are on the collaboration and partnership side, it is likely to initiate a troubleshooting when there is a mismatch in the common metrics. This will lead to an agreed choice of developing a shared metric that both sides will be using afterwards. Over the time this leads to optimizing the number of performance measures used by both sides. Therefore, waste (or muda in lean literature) of resources will be reduced by these actions of performance measurements which is also aligned with the whole lean philosophy.

6 NEW LEAN HOSE ASSEMBLY MANUFACTURING

In this chapter, the main product line of the case company Supplier Oy will be introduced as well as giving some historical changes in the manufacturing of it. Then, few information regarding the design process of Supplier Oy will be given while keeping most of the information classified.

6.1 KIT MANUFACTURING

Hose assemblies have always been vital components of machines in construction and mining industries. Enabling the transfer of extreme force, industry has developed a lot over the time. Basically, a hose assembly contains three major components which are shown in Figure 22 below.

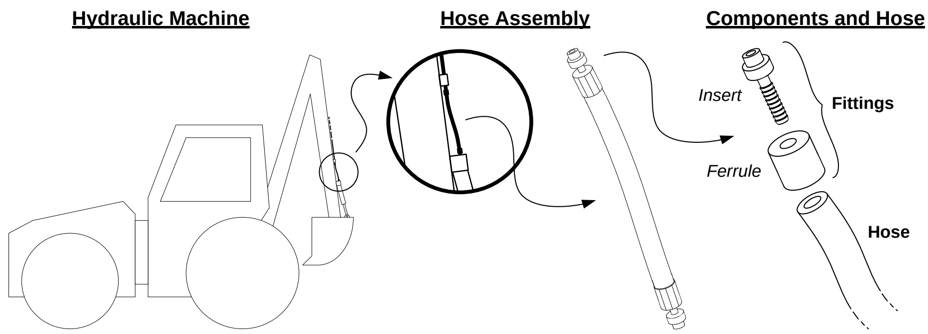


Figure 22. Hydraulic Hose Assemblies

Hose assembling process can be explained as the following. First the desired length is cut out of specific hose. Then, the ferrules and inserts are attached to its ends. Finally, the ferrules are squeezed radially that deforms them and attaches the hose and the fittings tightly to each other. Figure 23 below illustrates the hose assembling process briefly.

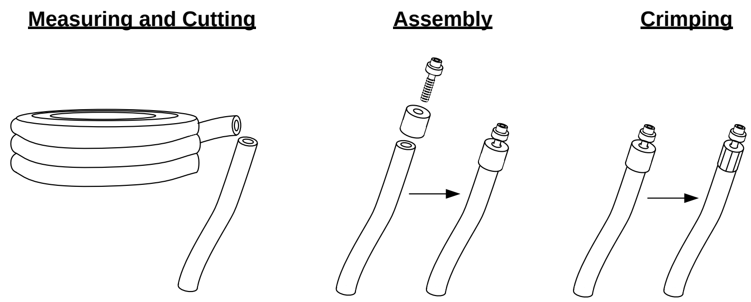


Figure 23. Hose assembling process

During the 1990s OEMs of hydraulic machinery started to change with the spreading philosophy of lean manufacturing. Some OEMs them even hired engineers from Toyota or arranged factory visits to Japan to understand and adopt to lean philosophy. Before the lean concept became this popular, hose assemblies were purchased in big batches and stocked in the warehouses of OEMs. Whenever there was a need to assemble a new machine, the process was carried out the following way. Someone from the warehouse collected the required hose assemblies and fed them to the production line. However, this required a vast amount of inventory space. Also a lot of warehouse people were required all the time to collect and combine hose assemblies to production lines. Due to the fact that OEMs had a large variety of machines in their product ranges, each of them required different sets of hose assemblies. This led the OEMs to stock all those high variety of hose assemblies and cost them a considerable amount of money and inventory space.

As mentioned before, lean manufacturing tried to minimize the inventory and required production by demand (pull) rather than production in advance (push). Machinery OEMs started to change their buying behavior. Instead of buying the same hose assembly in big quantities, they shifted to ordering “hose assembly kits” gradually. A hose assembly kit can be defined as the set of all hose assemblies which are used in one specific model of machine or a sub-system of it. Figure 24, illustrates the concept of hose assembly kit with a comparison to old hose assembly batches.

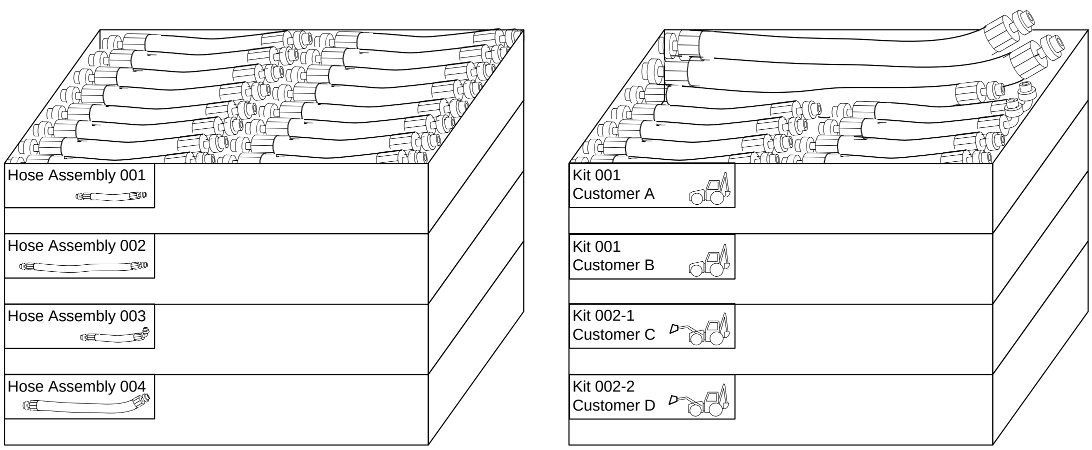


Figure 24. Batches of hose assemblies (left) versus hose assembly kits (right).

As it can be noticed in Figure 24, previously OEMs were creating these kits with out of their excessive inventories. This was causing a waste of resources and inventory space and it was not suitable for lean manufacturing philosophy. Also with increasing competition, OEMs were seeking for cost savings which could provide them competitive advantage. Certainly, having big inventories and purchasing big batches of hose assemblies were not suitable for this purpose. Therefore, with the change in this behavior of OEMs, the creation of the kits shifted from OEM side to their suppliers’ side. Hose assembly suppliers were now making hose assemblies and combining them into a kit before shipping. Kit purchasing was a highly efficient way to receive hose assemblies for production of hydraulic machinery. This eventually brought a pressure to the hose assembly manufacturers in terms of lead-time and production load. Now hose assembly manufacturers had the additional responsibility of combining the produced hose assemblies into correct set of kits for their customers. Since each kit consisted of several different hose types and lengths, it became a challenge for them to supply effectively as they were doing before.

Chaoji (2011) revealed in her case study with a hose assembly manufacturer, the productivity per man per hour is directly related with the current production order (Chaoji, 2011). Orders which consisted of the same or similar hose assemblies were completed much more quicker than the orders which contained different and complex hose assemblies which then formed into kits. This was due to the nature of hose assembly manufacturing. Changing the hose type and setup time of the machinery were the two major issues that decreased the productivity dramatically.

6.2 AUTOMATED CUTTING MACHINES AND KIT MANUFACTURING

Marken Manufacturing defined as an American manufacturer of equipment of hose assembly production. Among their wide product ranges, Marken Automated Cutting Machines are their specialty. Their machines can measure and cut hoses with extreme precision and accuracy. Compared to the traditional methods of measuring and cutting manually, the introduction of these automated cutting machines opened a broad set of opportunities. Although the automated cutting machines have been on the market for a long time, none of them achieved to be this reliable and accurate as Marken machines. There were few companies that attempted to develop automated hose cutting machines such as Hydroscand, OP and Clavel. However, all their machines required frequent measuring and calibration. When the cutting process started, it was often the case that first few pieces were longer or shorter than expected. Figure 25 (left hand side) below illustrates this problem.

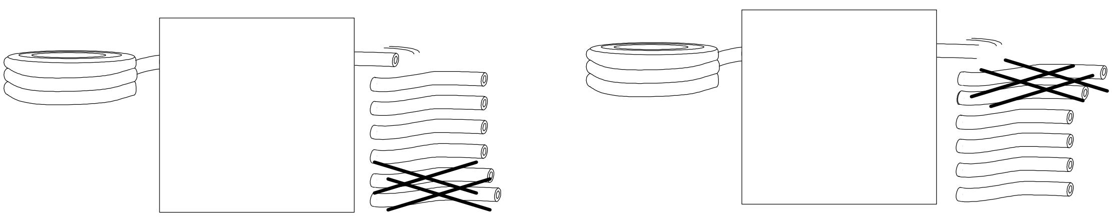


Figure 25. Problems with early automated cutting machines.

In the left hand side of Figure 25, first few pieces produced by the machine is not suitable to use and they were considered as scrap. Operators had to adjust the measuring parameters until the desired length is achieved. Then the machine was able to cut the same length without any further action. However even after calibrating it precisely, there were few instances where the machine started to shift towards longer or shorter hoses (right hand side of Figure 25 above). Therefore, the machines were not really reliable. Considering the machine behavior is already like this for fixed lengths, it can not be imagined to use these machines in kit production where the hose types and lengths change all the time. Therefore, a manual saw and a long measuring table has always been the choice of hose assembly suppliers in Europe.

However, Marken machines achieved to be highly reliable up to the point of cutting without constant supervision even for varying lengths and different hose types. Even though Marken offered fast and accurate cutting operation of the hydraulic hoses, they suffered from the bad reputation of automated hose cutting machines. Majority of potential buyers were thinking that it is too much investment for them and they were not convinced that the machines are able to cut that accurately. Therefore, it can be said that Marken suffered in the beginning due to poor performance of its predecessors. However, current stakeholders of the case company, Supplier Oy saw the Marken automated cutting machines as an opportunity to revolutionize the hose assembly manufacturing.

6.3 Expanding the Marken Idea and IT Enabled Further Development

Although Marken Manufacturing offered nothing more than accurate and reliable automated cutting machines, their product became a first step for the innovative idea of modern and flexible hose assembly manufacturing. Chaoji (2011), studied the productivity of a conventional hose assembly manufacturing company whose name is kept confidential in this thesis. According to her study, a traditional hose assembly manufacturing was running only with 20% efficiency. This means only 20% of the total time was spent as value added activities and the remaining 80% was mostly non-value added. She also revealed that kit manufacturing was the biggest cause of this inefficiency. Complex production orders were difficult to comprehend and produce for operators (Chaoji, 2011).

Soon after this revelation, it was realized that production cells can be formed with Marken machines for making hose assemblies rather than conventional, 10-meter production lines which had very large footprints on the production area. The idea was developed with the combination of creativity and hose assembly manufacturing experience. The details of the design process will not be given in this thesis due to confidentiality of the information. However, few general outlines will be introduced.

After analyzing the product statistics of potential customers, the material allocation to cells were done which was followed by the optimization of flow later on. One detail to notice here is the comparison of footprints between manual lines and

Marken cells. One Marken cell consumes around 50% of the traditional cell. Meaning that, in a confined space twice the amount of Marken cells can be implemented as compared to manual lines. After the initial discussion, lots of different layout configurations were analyzed and compared in order to find the most efficient flow of goods in the production. This became a lot easier after the production premises were decided on. Next step was to decide on the inventory space allocation and the optimization of production cell placements. Best scenario was chosen which would minimize the movement of goods through the production based on heuristics. Later improvements were added with the purpose of minimizing the mistakes.

One important aspect to be reminded here is that the IT intensiveness of the Marken One-Man Cell. Using the Marken machine as a primary data driver in the cell, all other features were made possible. With all these improvements, the development of the Marken One-Man Cell concept was completed. As an overall view, idea was developed around one automated hose-cutting machine and by exploiting the benefits that it may provide, the whole concept turned into something completely new. Since all the design was supported with Computer Aided Design (CAD) to the highest precision, it became very easy to implement these designs later on. In addition, the author of this thesis was deeply involved in the CAD design process of the factory, working closely with the experts in the hydraulic hose assembling industry.

The physical design of Marken One-Man Cell was only one aspect of the innovation process. Second step was to complete the functionality with a customized IT system. IT system was planned to drive the production and provide data to machinery for fast and flexible operation. For instance, when a kit order was received it would be processed and then production order of each hose assembly in the kit would be sent to corresponding production units (cells) for optimized production. IT system was highly complex due to the complex nature of kit manufacturing. In order to have proper functionality of Marken cells, a reliable and fast IT system was a necessity. Therefore, the IT specialists in the team developed a state-of-art to cover all these requirements. They are in fact still improving the features according to user feedbacks and customer requirements. With the implementation of the IT system the concept of Marken One-Man Cell was completed.

However, production was only one module of the IT system. There were other modules such as inventory management, order processing and procurement. One of the most important modules in the IT was the performance measurement module. This feature was intended to provide valuable information regarding the performance of Supplier Oy. Some of the measures are the following:

- Profit margin analysis
- Inventory consumption analysis
- Inventory value analysis
- Revenue
- Customer order status (open, confirmed or closed)
- On time delivery report
- Number of hose assemblies produced
- Cell load analysis

There are few more items that are not mentioned above, but these are the ones that are used most. It should be noted here that, the selection of metrics are correspondent with the previous literature review of this article, meaning that few of them are based on financial data. Majority of the metrics were chosen in a way that supports lean manufacturing philosophy. These metrics were reviewed by the management team of Supplier Oy periodically and proper actions are taken to make sure to steer the company aligned with its strategy. Metric of on time delivery performance is the focus of this thesis since it is directly related with the customer satisfaction.

7 ON-TIME DELIVERY PERFORMANCE

On-time delivery percentages are one of the most important performance metrics that lean companies value. Since they are following just-in-time delivery principles, it is crucial for lean customer to get what they need, exactly when they need it. Therefore while evaluating their suppliers' performance, reliable deliveries may tend to be rather important. In this chapter the case company's main customer and their challenges with their previous suppliers will be introduced first. Followed by the elaboration of key issues in delivery performance, how the whole idea of supplying metrics stemmed will be explained in detail.

7.1 CHALLENGES WITH THE PREVIOUS SUPPLIER

It was known that Customer had delivery performance related issues with their previous hose assembly supplier whose name is kept confidential in this report. According to the interviews with people in charge it was understood that the production philosophy of the previous supplier was quite extraordinary. After the change in the industry trend, which was the shift from batch purchasing to kit purchasing they faced some serious challenges. With the decreasing throughput, Customer experienced huge delays in the delivery of their orders. This can be explained by the time required to make hose assembly kits with the old traditional methods. It was proven that the productivity ratio of hose assemblies per man per hour decreases greatly if the manufacturer is producing complex kit orders.

As the supplier's inability to deliver on time persisted, a change in supplier's management philosophy was added on top of it. The management team decided that they were not going to initiate the production of the kits if they were out of stock for some components, hence unable to complete the kit. They chose to focus on the orders that they can manufacture completely and ship and invoice. Rather than sending the kit incomplete as a partial shipment and sending the rest of the items when they were in stock, this choice worsened the delivery performance even more.

While the on time delivery performance numbers in Customer was decreasing, Customer tried to solve the issue with the supplier but was not able to obtain any solid results. This forced Customer to consider their options for flexible hose assembly supplier who could be relied on in terms of consistent delivery performance. They became intrigued with the concept of Supplier Oy and observed their development phase closely. After the continued poor delivery performance of the previous supplier, they shifted their purchases from the old supplier to Supplier Oy just after the ramp-up of Supplier Oy.

However, problems started to arise a while after this switching. Decision makers of Customer Oy was checking the delivery performance of their suppliers and they noticed a very poor on time delivery performance of Supplier Oy. According to their business informatics delivery accuracy of Supplier Oy was around 30%. They requested Customer Oy Tampere branch to investigate this issue. After investigating they realized that there were some inconsistencies between the numbers on the computer screen and physical deliveries.

7.2 KEY ISSUES IN DELIVERY PERFORMANCE

There were some issues that caused the false numbers in Supplier Oy's delivery performance. Based on the discussion with the people in charge, there were few reasons that caused this appearance of the poor delivery performance of Supplier Oy.

- Forgetting to enter the received orders to the system
- Receiving delay
- Differences in performance measurement methods between supplier and customer

First, the investigation revealed that Customer was registering the arrival of their orders manually to their ERP system. The process was highly vulnerable to human error, since the entry process was completely a manual one. One person was responsible for checking every shipment and entering the order numbers into the system. This was not a reliable process since there is always room for forgetting to enter some orders with every shipment. Even though they were entered the next day or later upon realization, the system recognized the arrival of goods based on the date of entry. That was the first problem that caused the delivery performance of Supplier Oy to be lower than the actual situation.

Second, Customer Tampere decided to arrange their shipments from Supplier Oy twice a day. First shipment was scheduled around 9.00 a.m. and the second one was in the afternoon around 2.30 p.m. approximately. Considering that the operation hours of Supplier Oy is from 6.00 a.m. to 11.00 p.m. every day, there are few points that requires attention in this scenario. There is a production time of 8.5 hours that do not encounter shipping between the afternoon delivery and factory closing time. Even though, Supplier Oy completes orders in the evening shift they are not able to dispatch these goods until next morning. Figure 26 below shows this receiving delay issue.

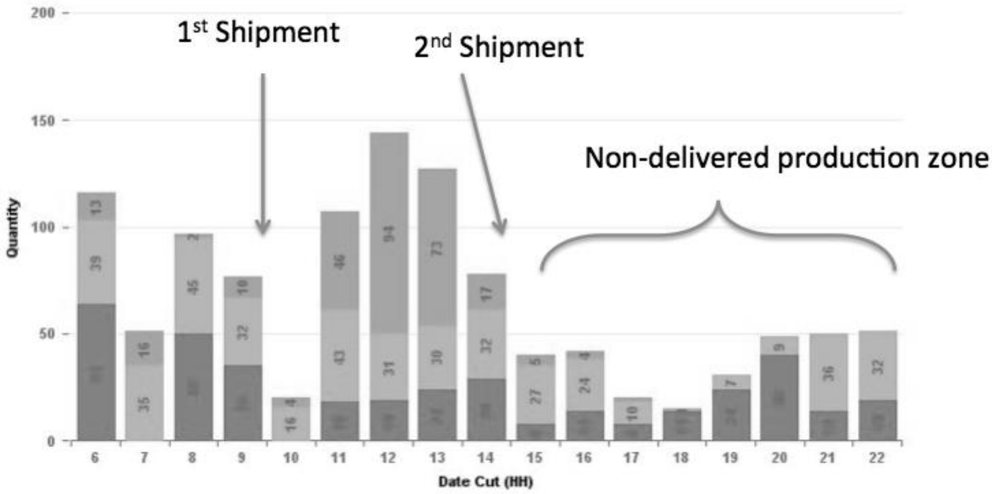


Figure 26. Receiving Delay.

As it can be seen in Figure 26, 8.5 hours of shipping delay corresponds to 50% of Supplier Oy's daily production capacity. When the orders that are produced in this time frame are shipped the next morning, this is most likely to create a considerable amount of receiving delay. Although attempts were made to question the possibility of production with one-day buffer, they did not seem to be likely since they were not suitable with JIT production philosophy. In the actual situation, the orders were completed on the required delivery date. However since no one was shipping them to Customer premises or there is no one to enter them to the system, Customer was measuring Supplier Oy's delivery performance lower than the actual performance. Several things were considered such as adding another evening delivery but it was not a plausible solution in this case, because orders also had to be entered into the system when they are received for a precise performance measurement. Third aspect of differences in measuring methods will be explained in detail in the following chapter.

7.3 Differences Between Customer's and Supplier's Measurements

As the investigation of the poor on time delivery performance of Supplier Oy was continued, a big difference was realized. The supplier and the customer had different results on the same measurement, regarding on time delivery performance of Supplier Oy. Customer measurements indicated a performance of 30% where as Supplier Oy measurement showed around 80%. This huge difference can be explained by the fact that two companies were measuring the delivery performance in two different methods. Customer was measuring it based on the manual entry of receiving as it was explained above, whereas Supplier Oy's method was based on the issuing date of the delivery note directly from computer system.

In Supplier Oy, order processing method was designed in a way that when the operators complete manufacturing of one order they bring the production papers to the person who is responsible for completing the production order by issuing the delivery note (lähete in Finnish) and invoicing the order later on. The architecture of Supplier Oy's delivery performance measurement was designed based on the issuing date of the delivery notes. It was previously agreed that delivery notes are issued right after the orders are physically manufactured and they were ready for shipment. Even though the orders are completed during the evening shift, the delivery notes were issued next morning as backdated, since it was believed to be a more accurate measure for production performance among Supplier Oy management team. Nevertheless, Customer Oy was not fully aware of this calculation method hence they even might have suspected the manipulation possibility of the Supplier Oy's performance measurement data as well as other reliability issues in the first place.

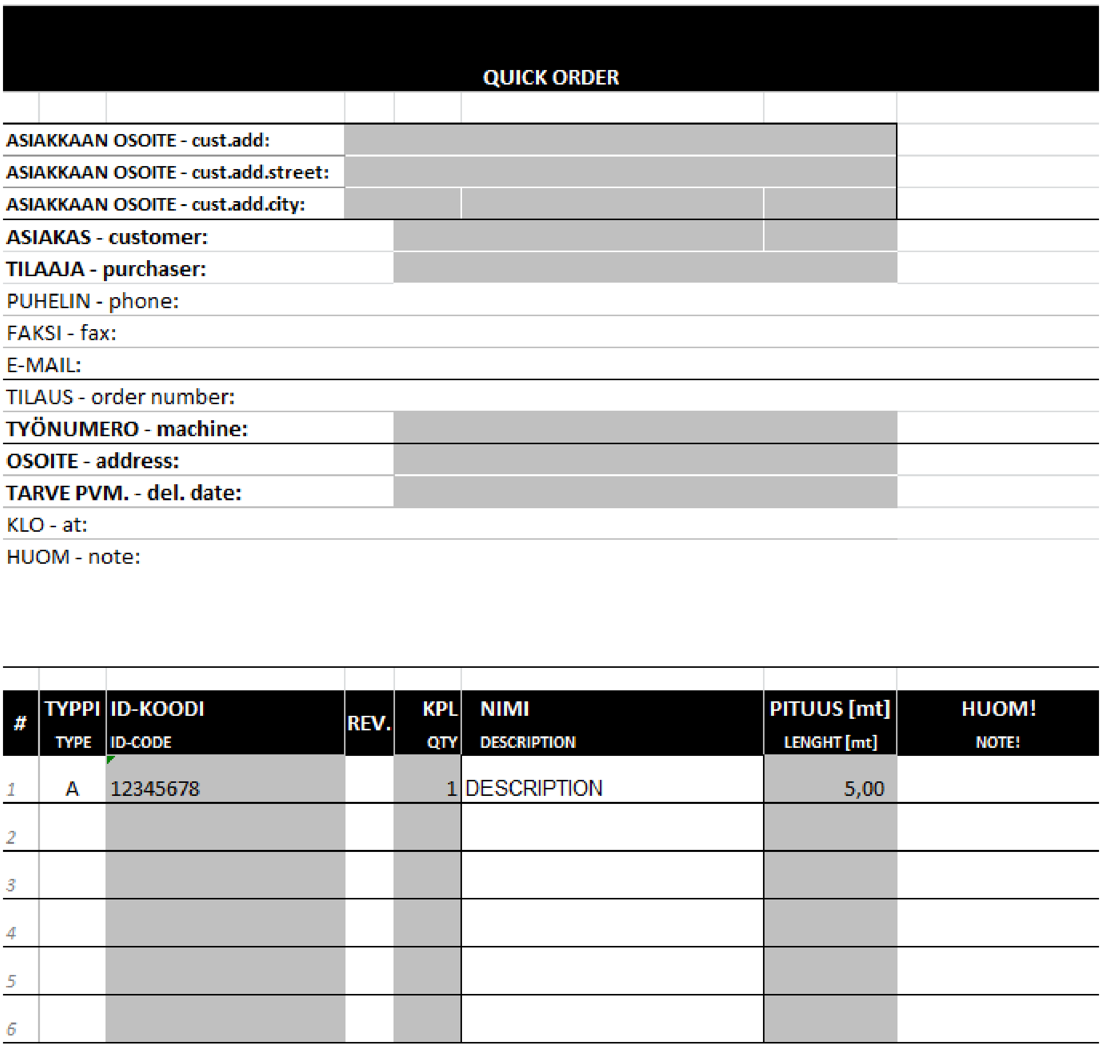
One of the reasons why Customer Oy's and Supplier Oy's performance did not match was the difference of measuring non-EDI orders. Customer Oy's purchasers placed their order in two different ways. One of them is EDI (Electronic Data Interchange) ordering and the second one is non-EDI ordering. EDI ordering is created by using the ERP software in Customer Oy and all the data is transmitted to Supplier Oy's ERP system with the help of a liaison software in the middle. Figure 27 below shows the architecture of EDI ordering.

Figure 27. EDI ordering.

As seen in Figure 27, EDI ordering is a two-way connection. Liaison software in the middle converts the data from Customer Oy into meaningful data for Supplier Oy ERP software. All the item codes and other data used in an order passes through this liaison program and Supplier Oy ERP is then able to process this order. Without going into further software related details here, it should also be mentioned that the process also works the same backwards. When Supplier Oy confirms an order, data is transmitted back to Customer Oy through the liaison so that Customer Oy is also able to view the statuses of their orders in real time. Furthermore, when an order is completed and invoiced, the invoices are transferred automatically to Customer Oy without any extra effort.

Non-EDI ordering is explained as the manual ordering process by email. Although this type of ordering is intended for customers who do not have the infrastructure for EDI ordering, Customer Oy purchasers sometimes place their orders via e-mail.

Quick orders (pikatilaus) which are defined as the orders with a delivery window of less than two days, are sent with email by using an Microsoft Excel file template. Figure 28 shows the template file.



QUICK ORDER

ASIAKKAAN OSOITE - cust.add:
ASIAKKAAN OSOITE - cust.add.street:
ASIAKKAAN OSOITE - cust.add.city:
ASIAKAS - customer:
TILAAJA - purchaser:
PUHELIN - phone:
FAKSI - fax:
E-MAIL:
TILAUS - order number:
TYÖNUMERO - machine:
OSOITE - address:
TARVE PVM. - del. date:
KLO - at:
HUOM - note:

#	TYPPI TYPE	ID-KOODI ID-CODE	REV.	KPL QTY	NIMI DESCRIPTION	PITUUS [mt] LENGHT [mt]	HUOM! NOTE!
1	A	12345678		1	DESCRIPTION	5,00	
2							
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Figure 28. Example Quick Order.

When an order is received with non-EDI methods, it has to be entered into the system manually. Apart from the fact that this is a highly time consuming process compared to EDI orders, quick ordering is a privilege given to Customer Oy purchasers. With the usage of quick orders, Customer Oy ensures that they get their critical items immediately with the expense of a slightly higher cost. However, this quick ordering mechanism is used more often than it was intended to be. Analysis of the data taken from Supplier Oy reveals interesting insights. Figure 29 below shows the distribution of types of orders based on 2306 orders.

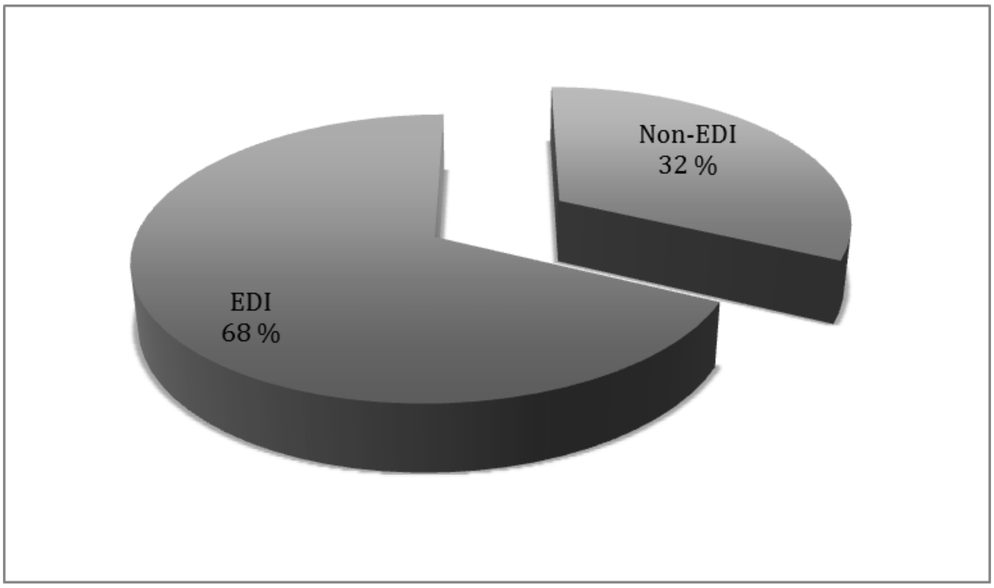


Figure 29. Distribution of Customer Oy order types.

Figure 29 is an actual proof of the mismatch. It was known that Customer Oy did not measure the delivery performance of their non-EDI orders whereas Supplier Oy measured all types of orders. Since the order was not placed by Customer Oy's ERP system, it did not show on their records. Hence this makes Customer Oy unable to track and measure the delivery of their receiving of quick orders. Obviously, purchasers know that whether their shipment has arrived or not but the whole process is carried off the record. Referring to Figure 29 above, 32% of Customer Oy orders are not included in the calculation of on time delivery performance. This could result in a huge difference between the calculation and the actual situation. In addition, quick orders have higher production and delivery priority as mentioned above.

Another issue comes from the actual production side as well. Since quick orders have higher priority than normal EDI orders, the manufacturing cells stop their current batches and start producing these fast orders when they arrive. This may sometimes cause delays regarding the scheduled completion time of EDI orders. Due to the fact that Supplier Oy delivers these quick orders first, delivery of EDI orders can be delayed depending on the situation. This is another aspect that creates the illusion of poor delivery performance.

8 TROUBLESHOOTING TO SUPPLIER MEASUREMENT

Initiation of the troubleshooting phase is the first step towards the solution of the problem. Although it can be initiated by the both sides, often the success of troubleshooting process depends on the attitude of the side which has higher bargaining power in the business relationship. In this chapter, the analysis of the mismatch of the metrics will be introduced. After that the idea of supplying performance metrics to customer will be explained with its potential implications on the customer side. Finally, some future possibilities which can be enabled will be told, in order to create a vision for the future reference.

8.1 CUSTOMER APPROVAL PROCESS

When there happens to be a mismatch between performance measurement of supplier and customer, the issues have to be solved for continued healthy relationship. Commitments of both parties are important in this sense, since they have to find a solution collaboratively to figure out why this mismatch has happened and how to solve it.

In Supplier Oy's case, the mismatch regarding on time delivery was realized in late February in 2013. While Customer Oy Headquarters was evaluating the performance of its suppliers, they realized that Supplier Oy's delivery performance was around 30%. In Supplier Oy however, the situation was quite the opposite. Figure 30 below illustrates this conflicting situation.

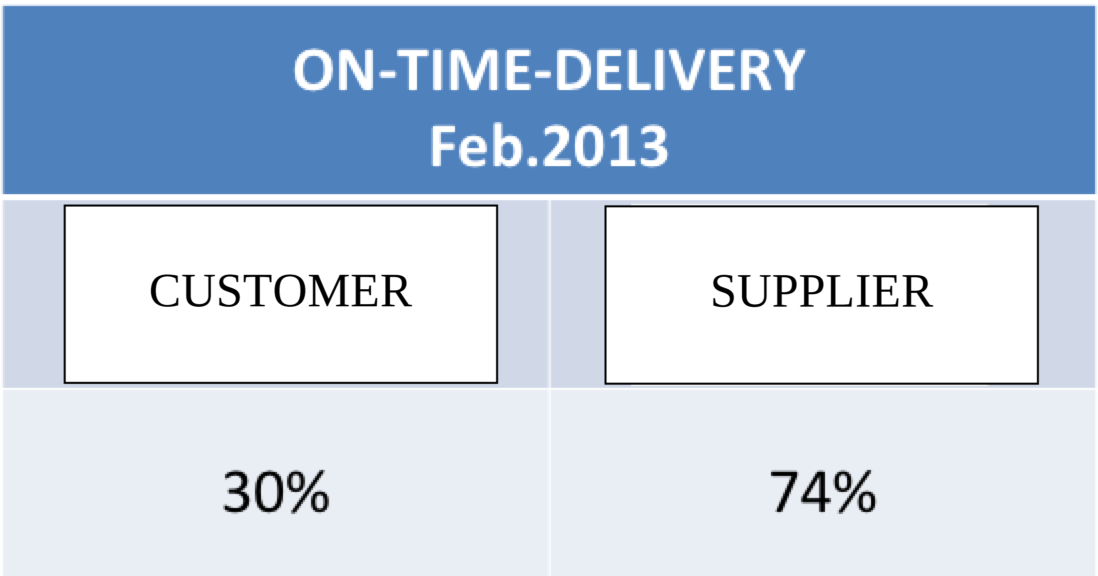


Figure 30. Difference between OTD measurements of both companies.

As it can be seen in Figure 30 above, business intelligence data was indicating a successful on time delivery percentage around 74%. Furthermore, Figure 31 shows the data extracted from Supplier Oy's business intelligence software.

2,012

October			November			December		
order lines	delivered on time	% OTD	order lines	delivered on time	% OTD	order lines	delivered on time	% OTD
1,398	859	61.44%	1,754	1,306	74.46%	1,240	1,206	97.26%
1,398	**859**	**61.44%**	**1,754**	**1,306**	**74.46%**	**1,240**	**1,206**	**97.26%**

2,013

January			February			March		
order lines	delivered on time	% OTD	order lines	delivered on time	% OTD	order lines	delivered on time	% OTD
1,708	717	41.98%	1,499	1,188	79.25%	1,593	1,454	91.27%
1,708	**717**	**41.98%**	**1,499**	**1,188**	**79.25%**	**1,593**	**1,454**	**91.27%**

April			May			June			July		
order lines	delivered on time	% OTD	order lines	delivered on time	% OTD	order lines	delivered on time	% OTD	order lines	delivered on time	% OTD
1,733	1,351	77.96%	1,471	1,376	93.54%	894	823	92.06%	46	46	100.00%
1,733	**1,351**	**77.96%**	**1,471**	**1,376**	**93.54%**	**894**	**823**	**92.06%**	**46**	**46**	**100.00%**

Figure 31. Supplier Oy's calculation of on time delivery performance.

Although it may seem that Supplier Oy's delivery performance was quite poor in October and November of 2012, it must be noted that Supplier Oy was still building up their production lines and upgrading them frequently at that time. This caused the delivery performance to decrease but it was expected to be so and known to be temporary. However what happened in February 2013 was unexpected for both sides. Customer Oy contacted their local branch, Customer Oy Tampere to examine this issue. Then, Customer Oy Tampere had several meetings with managing team of Supplier Oy. After checking on both sides, Supplier Oy claimed that their delivery performance measurement was showing good numbers. Soon it was acknowledged that the reasons explained in previous chapter turned out to be the causes of this huge mismatch.

The important aspect in this scenario is that instead of blaming each other and trying to justify their measurements, both the supplier and the customer approached the situation with a problem-solving attitude and tried to find out the possible reasons of this problem and how to sort them out. This is one of the requirements of lean philosophy that instead of competing with each other, suppliers and their customers tend to develop a close and long-term relationship. However, customer is often the side that is in possession of bargaining power and their decisions turn out to be exact from supplier's perspective. After the discussions, Customer Oy acknowledged that their performance measurement for on time delivery was not reliable for two main reasons:

- Not measuring non-EDI orders
- Receiving delay

After that point Customer Oy considered restructuring their performance measurement system, however an extraordinary yet highly useful solution was found: Using Supplier Oy's on time delivery measurements. Most of the time, customers are involuntary to rely onto their supplier's performance measurements, since the supplier can always manipulate them. Nevertheless, both Customer Oy and Supplier Oy have been trying to develop a long term relationship that they can both benefit from. That is the reason why Customer Oy gave approval to using Supplier Oy's measurement system to track the delivery performance. Supplier Oy was also highly in favor of such decision because they were aware that their measurement system would provide a more accurate and reliable data to their customer, when compared to their current one.

Apart from the fact of higher reliability, there can actually be more reasons why Customer Oy approved to use their supplier's PMS instead of their own. The possible reasons are listed below:

- Measurement of non-EDI orders
- Division separating
- Buyer separating

First, Customer Oy was not measuring their non-EDI orders namely their quick orders. However, Supplier Oy's performance measurement infrastructure was very easy to make proper modifications in a way that it can separate EDI and non-EDI orders. After doing that Supplier Oy was able to see their on-time delivery performance for two categories separately. This was a huge benefit from Customer Oy's point of view since they would be able to see the on time delivery performance of their supplier in more detail than they ever did. Figure 32 and 33 below shows the measurement of two separate categories after the modification of performance measurement system.

On Time Delivery Report (EDI ORDERS)

January			February			March			April			May		
order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD
1,708	717	41.98%	1,499	1,188	79.25%	1,593	1,454	91.27%	1,731	1,351	78.05%	1,471	1,376	93.54%
1,708	**717**	**41.98%**	**1,499**	**1,188**	**79.25%**	**1,593**	**1,454**	**91.27%**	**1,731**	**1,351**	**78.05%**	**1,471**	**1,376**	**93.54%**

June			July		
order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD
894	823	92.06%	66	66	100.00%
894	**823**	**92.06%**	**66**	**66**	**100.00%**

Figure 32. On time delivery report for Customer Oy EDI Orders.

On Time Delivery Report (STANDARD ORDERS)

January			February			March			April			May		
order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD
632	550	87.03%	615	496	80.65%	693	491	70.85%	734	625	85.15%	581	552	95.01%
632	**550**	**87.03%**	**615**	**496**	**80.65%**	**693**	**491**	**70.85%**	**734**	**625**	**85.15%**	**581**	**552**	**95.01%**

June			July		
order lines	delivere d on time	% OTD	order lines	delivere d on time	% OTD
487	451	92.61%	38	28	73.68%
487	**451**	**92.61%**	**38**	**28**	**73.68%**

Figure 33. On time delivery report for Customer Oy non-EDI orders.

Second, Customer Oy Tampere has two major divisions in their branch: (1) Division A and (2) Division B (names kept confidential). The names come from the usage area of the machines that they assemble. Although it was not fully implemented yet, after doing proper adjustments to Supplier Oy's performance measurement system it will be possible to see the on time delivery percentage of each division separately. Figure 34 below shows the template for on time delivery performance for separate divisions.

Delivery performance - [r.0.0.2]

June 2,013

Delivery performance

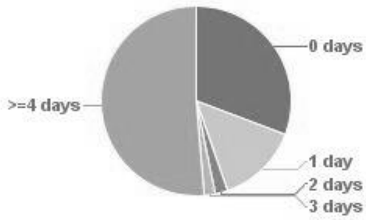
	Overall		Division A		Division B
	92%		92%		93%
	% OTD		% OTD		% OTD
week 23	82%	week 23	77%	week 23	81%
24	95%	24	100%	24	95%
25	99%	25	100%	25	100%
26	97%	26	100%	26	96%
	92%		92%		93%

Figure 34. On time delivery performance of individual divisions.

Third and probably the most interesting point in this change process is believed to be the separation of buyers individually. The idea is to reveal the average delivery window requirements of individual buyers and their relationship with the on time delivery performance. Figure 35 below shows the template report of each division’s purchasing statistics.

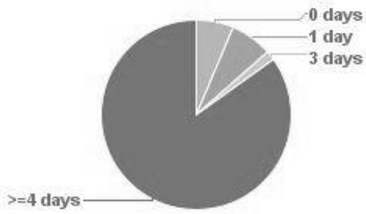
Delivery time

Overall



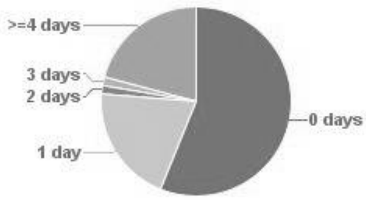
	Orders		Assemblies		EDI Errors (*)
0 days	115	31%	844	6%	0
1 day	52	14%	1,238	9%	0
2 days	8	2%	644	5%	0
3 days	7	2%	338	2%	0
>=4 days	192	51%	11,217	79%	0
Sum:	**374**		**14,281**		

Division A



	Orders		Order lines		EDI Errors
0 days	8	6%	16	2%	0
1 day	9	7%	165	3%	0
3 days	2	2%	1	1%	0
>=4 days	107	85%	4,763	94%	0
Sum:	**126**		**4,945**		

Division B



	Orders		Order lines		EDI Errors
0 days	78	56%	703	34%	0
1 day	28	20%	938	21%	0
2 days	2	1%	433	3%	0
3 days	2	1%	250	3%	0
>=4 days	29	21%	4,750	40%	0
Sum:	**139**		**7,074**		

Figure 35. Template report of divisions' purchasing statistics.

To conclude, more deductions can be done with the provided data rather than only seeing on time delivery performance reliably. These deductions will be examined in detail in the next chapter. From Supplier Oy's perspective all three benefits are expected to be available to Customer Oy without any of their extra efforts.

8.2 Potential Implications

The opportunities that will be coming from using Supplier Oy's performance measurement is indefinite. More and more possibilities are revealed as the change process advances.

Supposedly, the information that shows Division A and B orders individually will be highly valuable for Customer Oy since can use this information to improve their ordering process. Supposedly it will reveal the possible improvement areas for ordering process of Customer Oy which applies to not only to Supplier Oy but also to their other suppliers as well. All these information will be available to Customer Oy without any extra effort, after the full implementation of the idea. Considering that Customer Oy will not have to spend any time or resources to make these changes, it is quite understandable and justifying that they have been in favor of such change.

Combining the first and the third item from the possible benefit list in previous chapter however, opens many possibilities for Customer Oy. It can somehow imply that excessive usage of non-EDI orders (quick orders) may reflect a poor purchasing performance of Customer Oy’s buyers. As it was mentioned above Customer Oy has the privilege to place a quick order which can be delivered same day or the next day. Although Supplier Oy charges 10% extra when they receive a quick order, this is a reasonable way for Customer Oy to acquire their critical items quickly. Nevertheless if the amount of quick orders exceeds Supplier Oy’s order handling capacity, it will be expected that Supplier Oy will not be able to deliver these fast orders as quick as they are supposed to. Therefore, there must be a limit on the number of these quick orders to make the system work properly. Considering that it is always easier for Customer Oy purchasers to place quick orders and receive their items immediately, the amount of quick orders may sometimes tend to increase more than Supplier Oy’s expectations. In ideal situation, all orders are expected to be placed sometime in advance so that Supplier Oy can process the orders and plan their production schedules accordingly.

On the other hand, the measurement of buyer’s tendency to place quick order may be a perfect metric for the performance evaluation of the purchasers. In the case of Customer Oy and Supplier Oy where the supplying and purchasing is based on an agreed contract, there is alternative situation for Customer Oy to purchase from other suppliers. In normal case where there is more than one supplier, a good way to measure performance of purchasers is to compare the prices of identical or similar items. The buyer who can get the same items at a lower price than the others can be considered to be more successful. However in Customer Oy’s case this is not possible to use since all the purchasers are getting the same prices for their identical items. A good indication of purchasing performance is indeed based on the forecasting ability of the buyers. If buyers always know what they need and when they need it, they can place all their orders through EDI and allow their supplier more room to plan their production and delivery. With the comparison of two things, good amount of discussions can be created in Customer Oy which are:

- Average delivery window
- EDI to non-EDI ordering ratio

First, average delivery window can be defined as the time period between order creation date and requested delivery date. This is a parameter that is completely dependent on the purchaser’s decision. He may already know that he will need a hose assembly kit two months after and place the order accordingly or he may require it immediately depending on the situation. Although, it is acknowledged that forecasting is not always 100% accurate. Hence there will always be room for quick ordering.

Secondly, EDI to non-EDI ordering ratio is a strong metric for purchasers and can imply many things. If a buyer is placing all his orders with quick ordering mechanism, this certainly costs Customer Oy more and jeopardizes the smooth delivery of goods. In this case when a certain buyer is placing more orders than his partners, he is consuming production capacity out of other buyers' orders thus causing Supplier Oy to deliver their items later than expected. This will initiate a lot of questioning and discussions in Customer Oy and hopefully they will be able to improve their order scheduling or forecasting methods.

It must be reminded here that all these opportunities are coming from only using supplier's performance measurement system. Thinking that it will be available to customer without any of their extra effort, it should be understandable that Customer Oy is more than happy to access this data and use it for the future.

8.3 FUTURE POSSIBILITIES – CUSTOMER PORTAL

Based on the aspects that are mentioned above, possibilities that will be beneficial to Customer Oy are beyond the initial imagination. In addition to having more detailed and reliable data regarding their deliveries, there are few more future possibilities for Customer Oy. At the moment, a good guess can be a customer portal where Customer Oy purchasers and management team can access the data provided by Supplier Oy. An online web based portal can provide valuable information to Customer Oy in many cases. Some of these possibilities are:

- Tracking the production of every order in real time
- Tracking the status of their orders
- Delivery forecasting in case of a material shortage

Tracking the production and status of every order in real time is beneficial for both Customer Oy and Supplier Oy. When Supplier Oy releases the production of a customer order, the order is prepared and sent to production cells based on hose sizes and free capacity. It is known that Supplier Oy has access to the data that can be used to track each production order. With the help of IT department, simple software can be developed that shows the status on individual orders. Figure 36 shows an example of such case.

Order number	OC number	Status	Completion	Requested Delivery	Forecasted Delivery
A623445	OC/4044	Open		22.06.2013	
A443566	OC/3072	Confirmed		23.06.2013	23.06.2013
A456321	OC/3079	Released	0%	21.06.2013	21.06.2013
A665473	OC/4012	Production started	10%	21.06.2013	21.06.2013
A550784	OC/4010	Production started	75%	20.06.2013	20.06.2013
A650223	OC/4016	Production completed	100%	20.06.2013	20.06.2013
A675563	OC/3992	Material out of stock (FJ11B1212)		20.06.2013	25.06.2013
A644752	OC/3999	Shipped 20.06.2013	100%	20.06.2013	20.06.2013

Figure 36. Sample Web Portal Page.

As it can be seen in Figure 36, each order can be viewed individually and status reports can be seen immediately upon request. This will most likely be a powerful tool for both Customer Oy and Supplier Oy, since it allows both companies to see the production progresses separately. In this case, Customer Oy can have a better knowledge on their orders and see how they are progressing. One of the best parts of this scenario is that all the data is already available in Supplier Oy’s database, hence no extra effort is needed to make manual entries or updates to this web portal. Everything will be updated and processed automatically without having someone to enter separate data into the system. Now that the best possible scenario would be integrating Supplier Oy ERP system into Customer Oy’s ERP system which makes this feeding system of performance metrics official and accessible to everyone in Customer Oy. Nowadays this is carried out via automated email system to local decision makers in Customer Oy. However, it is definitely necessary to make this integration for better visibility and effectiveness of whole supplying performance measurement idea.

Another possibility is to extend this information system to other customers as well. With certain modifications, all customers of Supplier Oy can have access information to the web based customer portal and see the statuses of their orders. Excluding the transactional customers, it can be implemented for all regular customers. This certainly will be an added value for customers of Supplier Oy. Instead of calling or sending an email to inquire about the status of some orders, customers may simply login to portal and see the real-time situation of their orders whenever they want.

It must be reminded once again that all these possibilities can be made possible thanks to the IT intensive design of the whole system. Since One-Man Cell concept was designed and built in a highly computerized way, all future possibilities are not very difficult to implement. The ones that are mentioned above are just a few options that can be enabled very easily. Actual number of possibilities are at a bigger extent.

9 DISCUSSIONS

The analysis of the results provided highly unexpected insights into the performance measurement systems of both companies. From one perspective, it was revealed that both companies were measuring the same performance aspect. However the metrics which were supposed to be at the same level turned out to be highly different. In this chapter, the results of the troubleshooting phase will be analyzed. Later on, correlation with the theory will be given by using the framework as a tool. Future implications and the generalizability of the framework will be explained as well.

9.1 ANALYSIS OF THE RESULTS

Customer's attempt to question Supplier Oy on why the on time delivery performance was low, lead to realize there was a huge mismatch between the performance measurements. As it is indicated before, in February of 2013, the OTD percentages showed a greater difference. The fact is that they were slightly different all the time. However this did not concern any of the sides since everyone was content with the current numbers. When the customer realized that the percentage was considerably low they forwarded this issue to the supplier. This initiated the discussions and analyses regarding why the gap was so big between the measurements of both sides. After having few meetings with the customer and analyzing the internal data, it was found out that there are three basic reasons for such a difference:

- Forgetting the entry of received goods at Customer Oy side
- Receiving delay
- Differences in measuring methods

First, one warehouse person in Customer Oy is constantly entering the orders to the computer system as they are received. It is highly likely that the responsible person forgot to make entries for few orders at the time of receiving, especially when the shipment is large and containing lots of orders. The chances are this has happened more than once, hence causing the measurement on Customer Oy to indicate lower than actual on-time-delivery value. Furthermore, there is another proof for such claim. Time to time, Supplier Oy was receiving e-mail from Customer Oy purchasers who were asking whether their EDI orders were delivered or not. There were few instances that the questioned order was already delivered 1-2 days ago. This supports the initial claim that Customer Oy purchasers were not able to see their orders' "delivered" or "non-delivered" status accurately on their computer systems. It has to be noted here also that the entry method is believed to be the same for a very long time. Customer service responsible person in Supplier Oy states her opinion the following:

"I would say 80% of the time the orders they are asking about turns out to be already delivered."

Secondly, receiving delay is closely related with the shipping schedule between Customer Oy and Supplier Oy. According to supplier-customer agreement, the shipment truck would visit Supplier Oy twice a day at the following times:

- 9 a.m.
- 2.30 p.m.

Therefore, anything produced after 3 p.m. has to wait for the next visit of the truck, which is the next morning respectively. When put into numbers, the time from 3 p.m. and 11 p.m. which is the daily closing time of Supplier Oy corresponds to 8 hours. In other words, 8 hours would mean 47% of Supplier Oy's daily production runtime. This is a considerable amount of time, especially in lean philosophy companies where the delivery is planned to be just in time. However, solving this delay is not easy. The arrangement of an evening shipment could be costly and even with doing so, there could be no one to enter the orders as "received" into Customer Oy ERP system. On the other hand, theoretically Supplier Oy is preparing the orders ready for shipment on their requested delivery date, but they have to wait in warehouse until the next morning since there is no arranged shipment for the remaining of that day. This problem is acknowledged by Customer Oy. In addition, they were willing to accept the orders as "on-time" if they are produced the same day. This totally aligns with Supplier Oy's measuring method which is based on the issuing date of delivery notes. Therefore, this brought them closer to seeing Supplier Oy's measuring method as more reliable and willing to use their measurements as a baseline.

In addition to this information, it could be argued that whether the completing the production of an order should be considered as "delivered-on-time" or not. However, it must be reminded that both Customer Oy and Supplier Oy trying to follow lean manufacturing philosophy, hence just-in-time deliveries. Therefore, the delivery window can be expected to be quite short compared to other customers. In order to have a clear terminology, delivery window corresponds to following formula:

$$Delivery\ window\ = Requested\ delivery\ date - Order\ creation\ date$$

In order to explain the situation better, requirements of Customer Oy orders were analyzed and the histogram in the following figure is constructed using Supplier Oy ERP data.

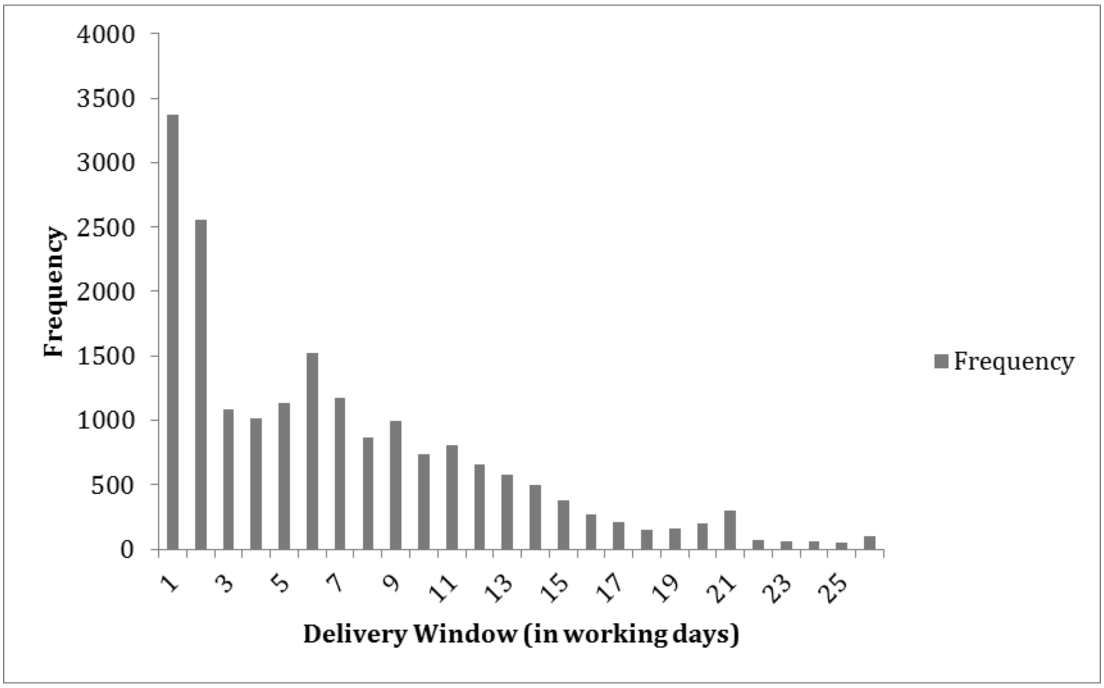


Figure 37. Delivery window requirement histogram (based on 19000 order lines).

As it can be seen in Figure 37, majority of orders contain a delivery window of 1 or 2 days. This supports the previous claim that delivery windows are expected to be short when companies are following just-in-time delivery. Therefore, the argument gets stronger that completion of production of an order should be considered as "delivered-on-time". Otherwise, majority of orders would be counted as same day delivery request, which puts a high production pressure on Supplier Oy. In addition, it could make the on-time-delivery measurement highly unreliable.

Third, the differences on what is measured and what is not was the root cause of the mismatch. It is strongly believed that this reason was the major source of difference between Customer Oy's and Supplier Oy's measurements. Although there is no way to calculate the contribution of each cause, numbers reveal that the biggest mismatch is likely to stem from this measuring difference. In order to explain in detail, Customer Oy was only tracking and measuring their EDI orders whereas Supplier Oy was measuring both EDI and non-EDI orders. Based on the meetings with Customer Oy, it was revealed that they do not have the architecture, nor the intent to measure their non-EDI orders. This is quite understandable, since measuring non-EDI orders might result in an excessive consumption of resources. Considering that Customer Oy's on-time-delivery performance measurement was solely based on EDI orders, a simple analysis was conducted to see the ratio for number of EDI orders versus total orders. Figure 38 shows the results of this analysis originating from the Supplier Oy's server data.

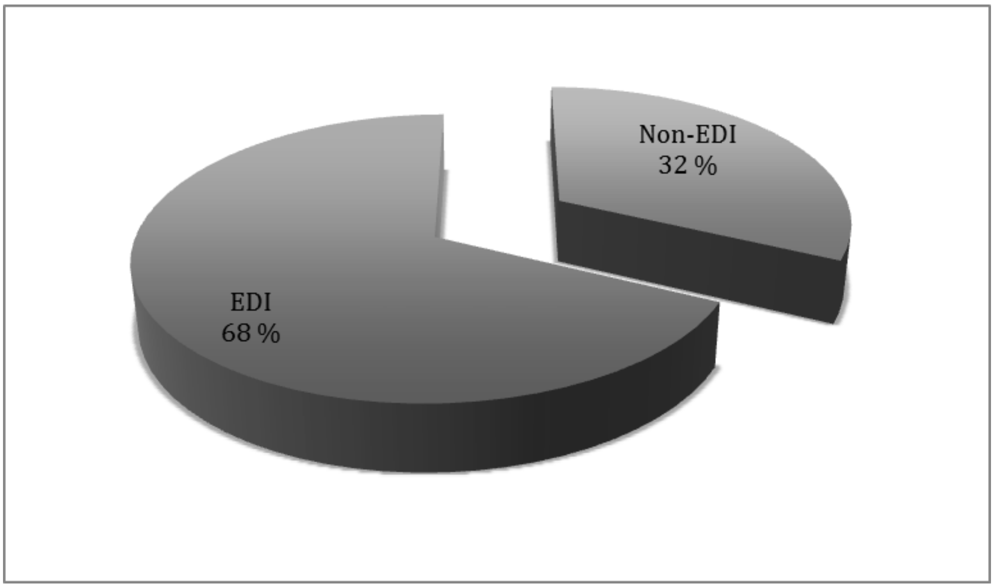


Figure 38. Distribution of Customer Oy's Order Types.

As it can be seen in Figure 38, 32% of Customer Oy orders are non-EDI meaning that they came either through email or other means. Remembering that Customer Oy was measuring only EDI orders, this could explain the big difference between two firms' on-time-delivery measurements. Customer Oy's measurement can be said to be 68% accurate only.

In addition, the mechanism of quick order (pikatilaus in Finnish) was given as an option to Customer Oy purchasers. This enables them to get smaller but urgent hose assemblies with a same day delivery. However, over the time it turned out to be so that quick ordering seemed easier for Customer Oy purchasers. It was too much of a struggle for them to use EDI engine to create kits and forward them to Supplier Oy, especially when they had to order some products directly from the assembly lines. Since quick orders have the highest priority in Supplier Oy's production planning, increasing number of quick orders started to delay the delivery of clean EDI orders. Obviously Supplier Oy had the capacity to react to this increases, however preparing the machines all the time was consuming a lot of time. Therefore, EDI orders sometimes experienced delay in delivery whereas in terms of customer satisfaction Customer Oy Tampere did not have a huge complaint. On the other hand, in terms of Customer Oy's measurement it started to get worse. Quick orders were now cannibalizing the delivery of EDI orders, which Customer Oy was only measuring. This also makes the EDI, non-EDI measuring more critical to cause the mismatch.

In this chapter the story of the mismatch was explained and discussed in deeper detail. Figure 39 below summarizes the discussions chapter in one figure.

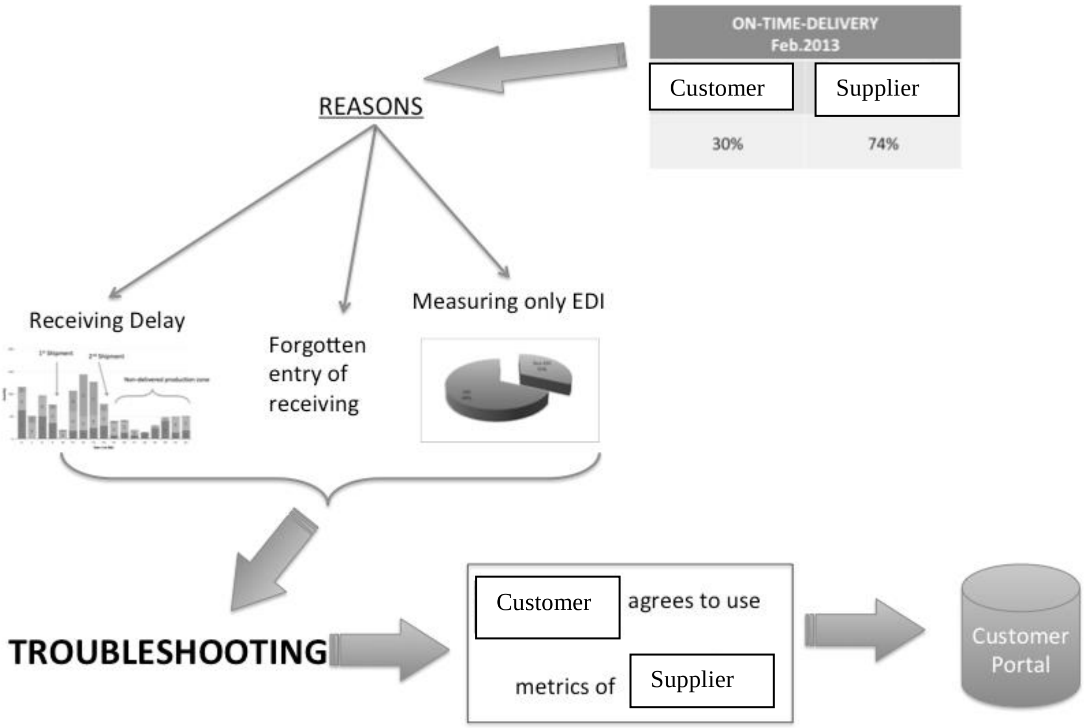


Figure 39. Summary of the case.

As it can be seen in Figure 39, when the mismatch was realized, the reasons were investigated and the trouble shooting phase began. After some time, Customer Oy agreed to use Supplier Oy's metrics since they were more reliable and valid. This brought the possibility of using a customer portal, where the customer will be able to see the status of their orders with many other value added features.

9.2 CORRELATION WITH THE FRAMEWORK

After Customer Oy acknowledged the open ends in their on-time-delivery measurement and started to move towards using Supplier Oy's metrics, a unique phenomena seemed possible to happen. Supplier Oy would be supplying not only products, but also their performance measurements. In this chapter reflections of the actual case onto the literature review will be explained using the framework developed in Chapter 5.

It was explained before that Customer Oy started to follow lean manufacturing philosophy in 1990s. Also, Supplier Oy which is still a rather new factory concept was developed to operate as lean as possible. Based on the historical change, it can be claimed that the relationship between Customer Oy and Supplier Oy has evolved. Figure 40 below illustrated this change and shows its effects.

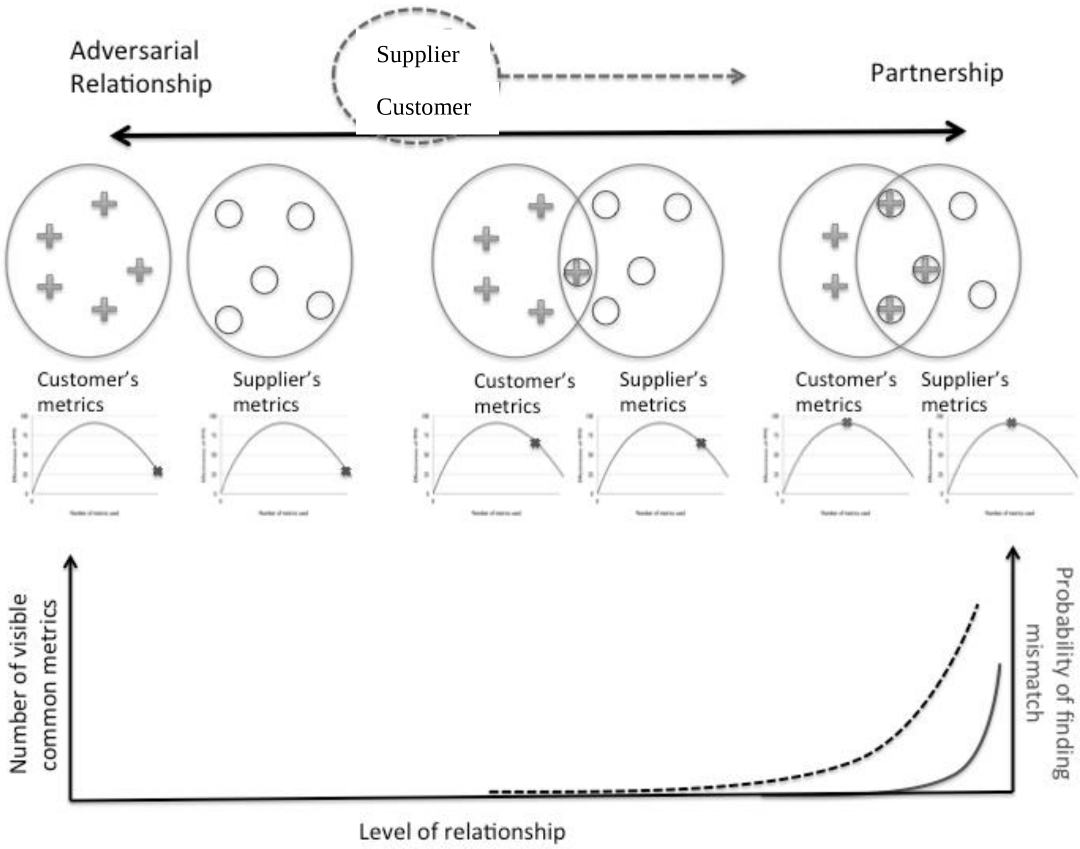


Figure 40. Change of relationship between Customer Oy and Supplier Oy.

As it can be observed in Figure 40, relationship between Customer Oy and Supplier Oy was already somewhere in between adversarial relationship and partnership. Although their relationship was not purely transactional, they did not have any shared metrics before. According to framework, the probability of finding a mismatch is 0 which correlates with the past situation. As the level of relationship deepened, their metrics became visible to each other, hence the possibility of finding a mismatch was born. After some time obviously they realized a mismatch between their metrics hence the troubleshooting phase began. The process turned out to be so that, Customer Oy would consider using Supplier Oy's on-time-delivery performance measurement. It would definitely result in the minimization of overall number of metrics, which also correlates with lean philosophy in terms of waste reduction. Figure 41 shows the current position of both companies.

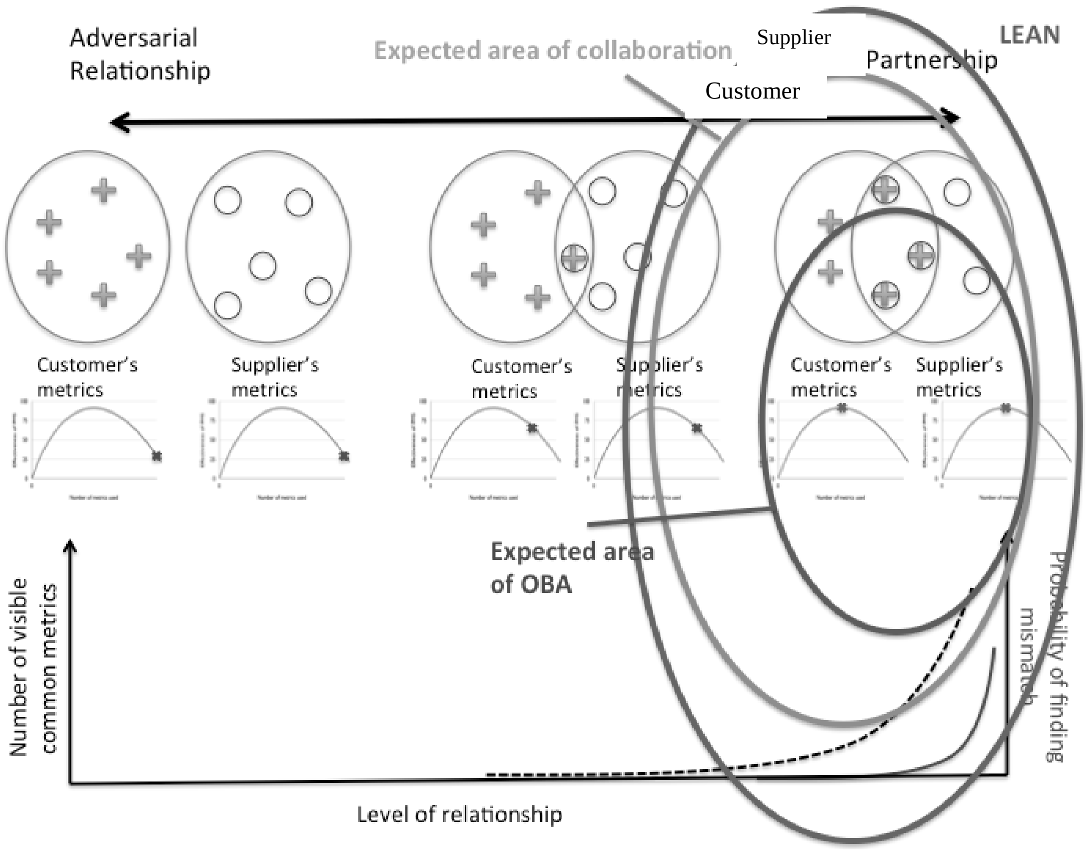


Figure 41. Current position.

As it can be seen in Figure 41, now both companies are getting inside to the interest zone of lean manufacturing which is partnership, ultimately. Both firms reduced the overall number of metrics, resulting in more efficient PMS and benefiting both sides. Also they are now sharing more performance metrics with each other, which may even create more possibilities in the reduction of overall number of metrics. From another viewpoint, they are now in a more collaborative manner with each other. This could also be supported with the troubleshooting phase that started after the finding a mismatch. Instead of blaming each other with poor measuring or manipulating the metrics, both Customer Oy and Supplier Oy discussed about the problem and tried to find out the reasons for such mismatch. With the issue resolved now it can be claimed that both parties are at a better position.

Another conclusion that can be drawn from the figure above is that both companies are almost in the zone for expected area of open book accounting (OBA). That is in fact supported by real facts. Customer Oy and Supplier Oy can be said to have partial open book accounting practices, meaning that Customer Oy can see the raw material purchases of Supplier Oy. However, in order to have a higher degree of OBA, it could be necessary that both companies are equal size. Considering the current situation, it is not supposed to be beneficial for Supplier Oy to see the books of Customer Oy. Nevertheless, when Customer Oy is inspecting the material purchase costs of Supplier Oy, they have the possibility to see possible cost reduction areas. These cost reductions eventually can be beneficial both parties in future. In addition, since Customer Oy might have a higher bargaining power, they can discuss some unexpected price raises directly with the suppliers of Supplier Oy.

9.3 FUTURE IMPLICATIONS

The activities of sharing performance measurements initiated a troubleshooting phase due to the presence of differences between two sides. After the troubleshooting phase, it was revealed that on time delivery performance measurement was more valid on one of the sides. Therefore, it was quite reasonable for Customer Oy to use that metric rather than insisting on their own. This brought the topic of what else Customer Oy would be willing to see in future, to the table.

There are two more important metrics that became visible to Customer Oy now. These are:

- Average delivery window requirements
- EDI / non-EDI ratio

First, average delivery window measurement can have implications on two aspects which are (1) Individual buyers, (2) Overall company. Individual buyers may have different ordering characteristics. For instance, one buyer can place his orders in advance as long as three weeks, whereas another buyer may keep ordering with very short lead time requirements. Obviously shorter lead times bring more pressure to Supplier Oy’s production side and requires more intensive production planning activities so that everything is delivered on time. On the other hand, average delivery windows can be a good metric of how lean the company is operating. If Customer Oy are ordering with too long delivery windows, it could result in waiting waste or excessive inventory for them.

Second, EDI / non-EDI ratio can be a good evaluation of buyer’s performance measurements. Under ideal circumstances, a buyer is not supposed to place quick orders (pikatilaus), assuming that he calculated all his required hose assemblies accurately. Surely, there could be errors or extra needs for some hose assemblies. However, if a specific buyer is excessively ordering quick orders all the time; it could easily mean that he did not plan his purchasing activity properly. In addition, the buyer who is placing quick orders to Supplier Oy all the time can be said to “cannibalize” the production of other orders. Since quick orders have higher priority than others, excessive quick orders can jeopardize the reliable deliveries of other EDI orders. That could also be an interesting topic for Customer Oy to analyze and optimize their purchasing activities.

Since it was explained Supplier Oy was designed to be highly IT intensive company, all these performance measurement required minimum amount of human interaction. Calculations were based on solid facts and driven by a complex IT system. Therefore, it was not so difficult for Supplier Oy to measure many different things with a low usage of resources. Some metrics such as productivity or profitability was rather accurate than most of the other PMS. Although there are few limitations of time delay in the calculation of profitability or ROI, it seems so that Supplier Oy management team can make decisions quite easily by using the current system.

It was later thought whether Supplier Oy should provide some information mostly related with production to its customers as a value added service. Production information and order tracking is believed to be highly valuable for purchasers. One of the initial thoughts was that it could be very beneficial for Customer Oy purchasers to see the status of their orders in real time. Therefore, they could have access to all information which could be required from the assembly lines. Hence, it could easily result in a more efficient production planning for Customer Oy. In addition, in case of a material shortage they could easily see what is the forecast for the delivery and choose whether they want to receive shipment partially or keep it waiting at Supplier Oy premises. Obviously, developing such architecture requires to use some IT resources from both sides. However, the possibilities it provides could be highly beneficial. Appendix 2, shows the sample table for such scenario, which could be used by both Supplier Oy and its customers. Development of system required to usage of such table is considerably easy due to the IT intensive nature of Supplier Oy. It is unknown yet whether Customer Oy would be interested in such a system, but it is definitely an item on the future discussions agenda.

9.4 GENERALIZABILITY OF RESEARCH

The research conducted in this thesis approached the situation based on one real life case between a supplier and its key customer. Customer Oy's approval of using Supplier Oy's on-time-delivery metric instead of their own is seems to be quite unique phenomena when the current literature is considered. In many cases customer could be concerned about the reliability of the data supplied since it could be manipulated easily. However, IT intensive design of Supplier Oy and the current level of trust between parties overrides this fear. Also in certain cultures, some customers may be unwilling to use their suppliers' metrics just because of prestigious fear, even though suppliers' metrics would be more reliable and valid. However, this could be a subject to another research for organizational behavior study field.

The framework which is introduced and explained in this thesis appears to be applicable to other cases and companies. Although, more case studies has to be done to support this claim, a generic approach is the following: When a supplier and customer shares more metrics with each other eventually they will find some mismatch between their common visible metrics and initiate troubleshooting phase. In this case, the metric was on-time-delivery. However, it could be some other metric in other cases. Considering the performance measurements from a holistic point of view, few possible metrics can be immediately guessed which are subject to mismatch:

- Packaging cost
- Order lead time
- Transport cost
- Quality related metrics

The list can be extended, however not done so due to the context dependent nature of such cases. For instance, in overseas shipping the order lead time seems to be a vulnerable to a mismatch, since the transport distance is long and transportation is subjected to delays which are not directly related with the supplier. In that case of troubleshooting, a more reliable means of transport can be searched for the sake of both parties.

To conclude from the generalizability point of view, author believes that the framework can be applied to the other performance measurements as well without any difference. As long as there is enough information sharing, trust and collaborative manner, troubleshooting is expected to yield on using the metrics from one side. Hence it should result in a reduction of waste in excessive metrics without any issues, when both companies are considered. Nevertheless, it would be difficult to say which metric could be the subject in another case or how the troubleshooting phase would be finalized for other cases. More case studies can be conducted to support these claims in different contexts.

10 CONCLUSIONS

Lean manufacturing has brought big changes in various areas of manufacturing processes. Originating in the 80s, it was promising great benefits such as cost reduction, higher productivity, higher quality and so on. Lean philosophy's aim is to achieve all these by reducing the amount of waste (muda in Japanese), which stems from the non-value added activities. Although there are different categorizations, general agreement is that there are seven areas of waste which are:

- Transport
- Inventory
- Motion
- Waiting
- Over-processing
- Overproduction
- Defects (Hajek, 2009).

There are various tools and method aimed to reduce waste in the areas mentioned such as 5S programs, Quick changeover tools or Poka-yoke. Each of these are just tools to follow during manufacturing and their applications are highly context dependent. It also does not mean that only using those tools will provide lean manufacturing automatically.

Lean manufacturing brought some changes to manufacturing layouts as well due to the change from bigger lots to smaller lots with higher variety in the product mix. Manufacturing in smaller lots resulted in a loss of efficiency, an increase in cost and a decrease in productivity. Traditional layouts of job shop and flow line were no longer suitable to manufacture higher variety of products. Therefore the concept of cellular manufacturing, a sub portion of group technology was developed (Elleuch et al., 2008). The aim was to use the similarities of manufactured parts, hence physically grouping the machinery in a logical manner to deal with high variety and lower demand (Klippel et al., 1999). Few benefits that cellular manufacturing was promising are listed below:

- Reduced Work-in-progress (WIP) inventory
- Reduced set-up times
- Less material handling costs
- Reduced materials movement
- Increased throughput (Kumar & Hadjinicola, 1993; Elleuch et al., 2008; Yang & Deane, 1996).

As it can be immediately recognized from the list above, these benefits were aligned with the philosophy of lean, which is the reduction of waste ultimately. However, cellular manufacturing could also experience some drawbacks if not designed properly. Some disadvantages related with flexibility and load balancing between cells can cause severe effects and may result in a poorer efficiency (Marsh et al., 1997). Therefore, the design phase of the manufacturing cells has to be done thoroughly.

Another concept explained in this thesis was the performance measurement systems. Measuring is defined as quantifying something in desired units. In every measurement, generally there are two main criteria that tells how successful is the measurement which are: (1) Reliability, (2) Validity. Although there are other aspects such as feasibility or relevance, these are basically two major ones. Performance measurement on the other hand, was defined as a set of activities that are intended to help managers to analyze the current situation and guide their decision making processes. In addition to this, performance measurement systems (PMS) are considered as a set of performance measurements selected to serve as a basis for decision making (van Schalkwyk, 1998).

Lean manufacturing also brought some changes in performance measurement systems as well. Traditionally, performance measurement was not a common concept. However with the influence of lean manufacturing, it was proven that the activities of performance measurement became more common (Neely, 2005). Not only performance measurement systems became more widespread, but also they evolved over the time with requirements of lean philosophy. Historically, most of the performance measurement systems were based on financial data. However, with the other requirements explained under lean philosophy such as quality or customer satisfaction, these conventional systems failed to be useful for decision making. Therefore, it was necessary to measure and analyze non-financial metrics as well as the financial ones. The most important aspect in PMS is making sure that the PMS is suitable for the strategy of the company and firms are measuring the right things in a right way. Most of the time, companies are wasting their resources on excessive metrics. Hence, while remembering back to the waste areas in lean manufacturing, the following item can be added to the list:

- Transport
- Inventory
- Motion
- Waiting
- Over-processing
- Overproduction
- Defects (Hajek, 2009)
- **Excessive metrics.**

In order to minimize the waste of resources, performance measurement systems also have to be optimized. It was also explained that as the number of metrics increase, the efficiency of PMS decreases which makes the decision making process even more difficult.

Lean manufacturing again, also triggered some degree of evolution to customer supplier relationships. Previously companies were more on the adversarial side of the relationship span. With the evolution, more and more enterprises shifted towards partnerships since it could provide them more competitive advantage than a standalone position in the markets. However in order to form partnerships and develop closer relationships, some certain level of trust is necessary. Open book accounting which can be explained as transparent books between two partners, also aims to reveal cost reductions that can benefit both partners. It was explained that open book accounting also correlates with lean philosophy and could be the first step towards information sharing. As the level of trust intensifies, more and more information is expected to be shared between organizations. Considering all these aspects a framework was developed in this thesis. Figure 42 below reminds the three aspects which the framework was developed around.

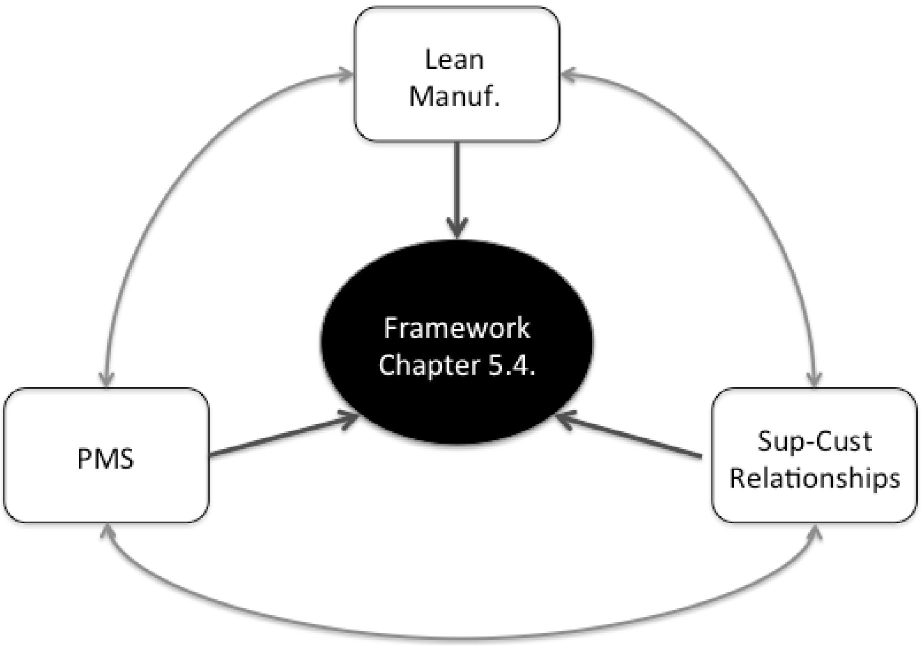


Figure 42. Components of the framework.

As shown in the figure above, all three dimensions contributes to framework. However the role of lean manufacturing can be considered to be more important, since the others are evolved by the initiatives of lean manufacturing. It was explained that as the level of relationship intensifies, more and more information is expected to be shared between parties. With this information sharing activities, common performance measurement metrics become visible to both sides in close relationships. As the common metrics become visible to each side, the probability of finding a mismatch between metrics increases. Since both parties are supposed to be in a collaborative manner, this is likely to lead them into troubleshooting phase. At the end of troubleshooting, it is highly possible that one side's measurement is more valid and reliable than the other. Therefore, it can be proposed that both sides can use and make decisions based on the better metric without any problems. This results in a reduction of overall number of metrics, which can also be considered as a waste of resources. Therefore, whole process seems to be aligned with lean philosophy from a holistic viewpoint.

Reflecting to the case, purchasing behavior of OEMs changed over the years with the influence of lean philosophy. They shifted to ordering kits of smaller batches from traditional ordering in big batches. Due to this changing nature, traditional manufacturers were no longer able to deal with the high level of variety, namely kit manufacturing. They were suffering from low productivity which yielded in poor delivery performances. Supplier Oy came as an alternative to traditional hose assembly manufacturing. Supplier Oy was developed as a lean company to follow cellular manufacturing in hydraulic hose assembly production. In addition, it could be claimed that the design process of the manufacturing cells were quite extensive and design team spent a considerable amount of time into the project which made the implementation phase rather easy and accurate. Comparing with the traditional manufacturing, Supplier Oy today is one of most efficient hydraulic hose assembly manufacturers in the world. It could even be said that cellular manufacturing is giving its promised benefits to Supplier Oy by all means.

The problem started in the early phases of Supplier Oy was that the two companies, Supplier Oy and their main customer Customer Oy, realized a mismatch between their on-time delivery performance metrics. Since both firms were eager to solve this mismatch, troubleshooting phase began. After long discussions few reasons were found as a source of this mismatch. Mainly, Customer Oy's performance measurement system was not reliable enough to measure everything. Hence this made Supplier Oy's metric more accurate and precise when compared to the customer's metric. Finally, Customer Oy agreed to use Supplier Oy's on-time delivery performance measures instead of their own, while evaluating Supplier Oy. This made Supplier Oy a supplier of both product and consecutive delivery performance data. Since Supplier Oy was developed as an IT intensive company, more and more possibilities were enabled for future reference.

Findings of this thesis were, the framework was suitable and aligned to analyze the conflict and troubleshooting phases of two companies: Customer Oy and Supplier Oy. In the beginning the two companies were just developing their relationship and after the troubleshooting phase it can be said that now they are in a closer relationship with each other. In addition, sharing performance metrics between companies can be considered as a broader practice of OBA. OBA focuses only on financial data, whereas shared metrics can be either financial or non-financial. Considering the change in performance measurement systems and their shift towards non-financial measurements side, it is expected that majority of shared metrics could be non-financial. Both OBA and supplying performance metrics being a novel area in the literature, more research can be done to support the benefits of these information sharing activities in lean partnerships. Since it was proven that using the other sides metrics can sometimes result in a better measurement system for both sides and healthier decision making processes in close business relationships. Therefore, both these grey areas could be illuminated with more case studies and widespread practices.

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APPENDIX

APPENDIX 1: Raw Data for Delivery Window Histogram

Bin	*Frequency*
1	3374
2	2557
3	1086
4	1015
5	1136
6	1523
7	1172
8	867
9	994
10	739
11	804
12	656
13	576
14	498
15	375
16	266
17	210
18	147
19	163
20	196
21	298
22	70
23	62
24	62
25	51
More	100

APPENDIX 2: Sample Customer Information Portal Table

Customer ID	Customer Order Ref	Customer Order Date	OC number	Requested Delivery Date	Status	Batch number	Booking percentage	Pathway in Production	Booking info	Production percentage	Remaining number of assemblies	Shipping date	Last transaction stamp
Customer1	A104279	11/10/13	6499	28/10/13	In production	131022-02	100%	L01+M01+S01	-	85%	35	-	28/10/13, 11:05, S02
Customer1	A102919	09/10/13	6223	14/10/13	Shipped	131007-13	100%	L01+M01+S02	-	100%	0	10/10/13	09/10/13, 21:45, S01
Customer1	A104125	10/10/13	6225	27/10/13	Released	131022-05	98%	-	SSFJ11B1212 (2 pcs short)	0%	225	-	-
Customer1	A104332	28/10/13	6605	01/11/13	Confirmed	-	-	-	-	-	138	-	-
Customer1	A103995	01/10/13	6338	10/10/13	Completed	131005-03	100%	L01+S01	-	100%	0	-	09/10/13, 09:02, L01
Customer 2	O25568	25/10/13	6238	28/10/13	In production	131025-05	100%	S01	-	95%	10	-	28/10/13, 10:58, S01
Customer 3	WN21558	28/10/2013	6609	01/11/13	Open	-	-	-	-	-	-	-	-